This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008324 (ChETEC-INFRA).

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

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

ChETEC INFRA

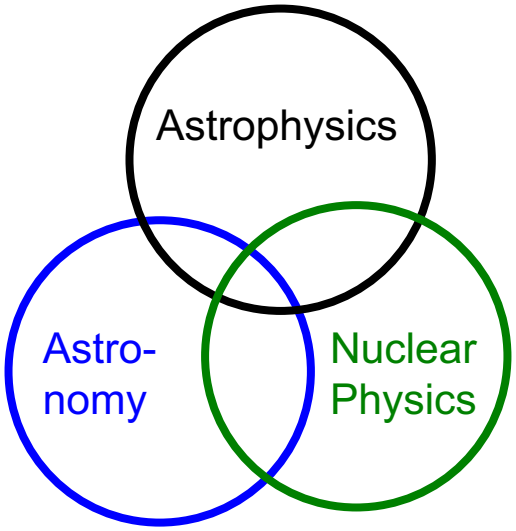
„Nuclear Cookies“ seminar
University of Padova
Tuesday 29.06.2021, 11:00

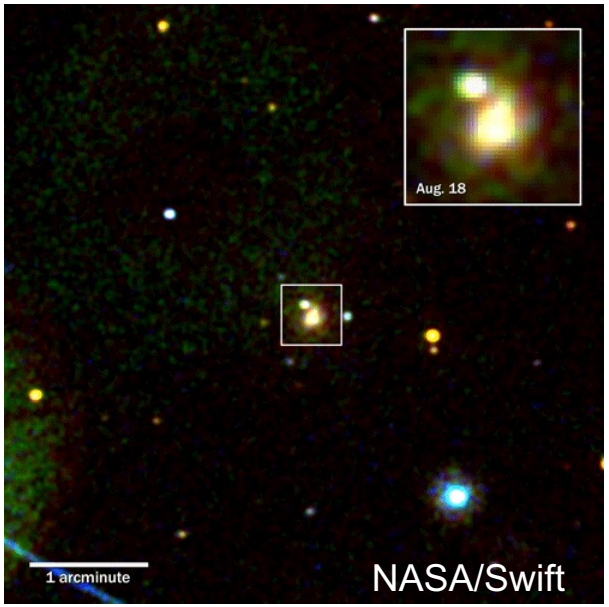
Daniel Bemmerer
HZDR Dresden, DE

www.chetec-infra.eu

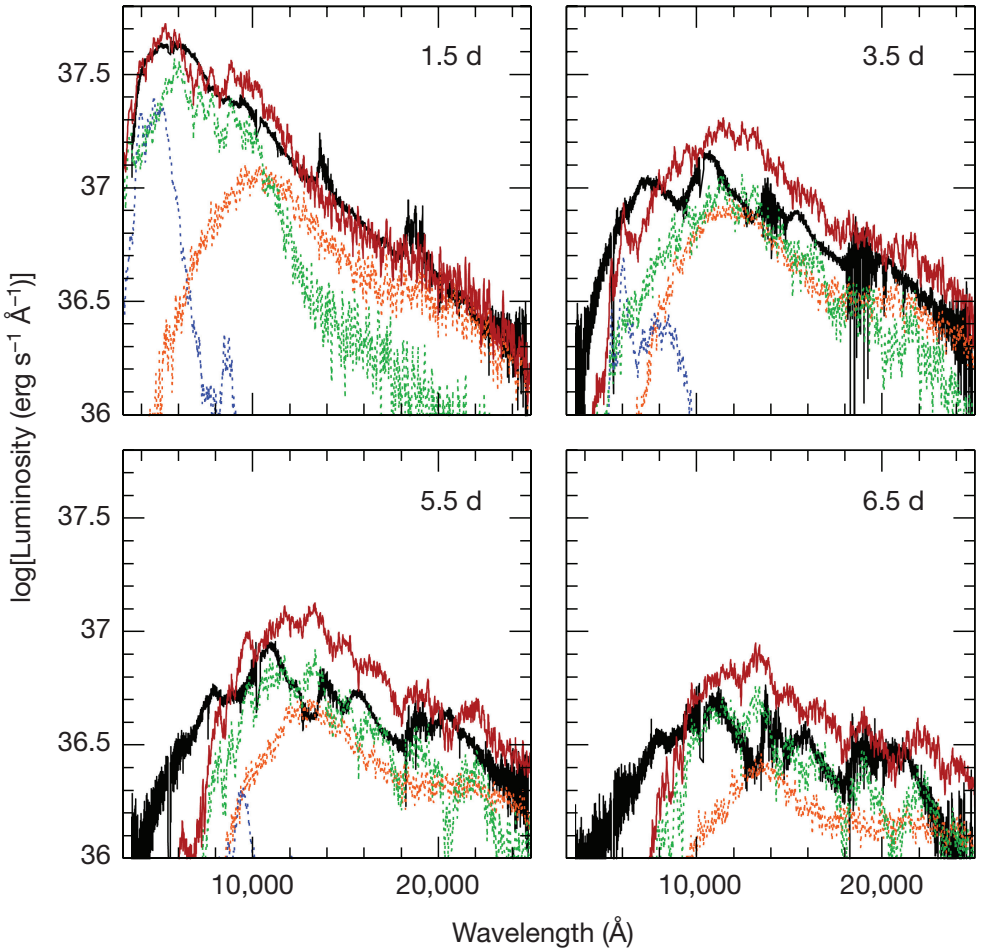
DRESDEN concept

Nuclear astrophysics at the intersection of three disciplines

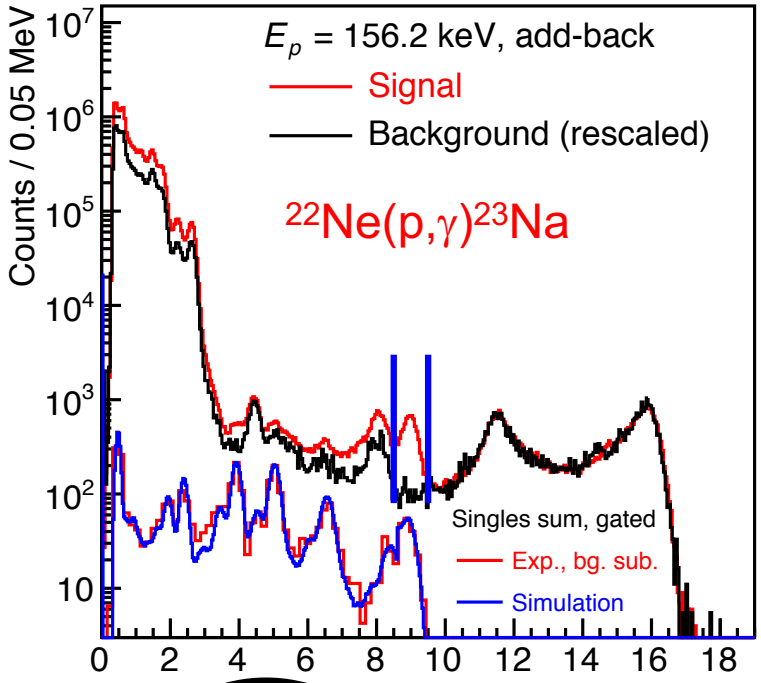




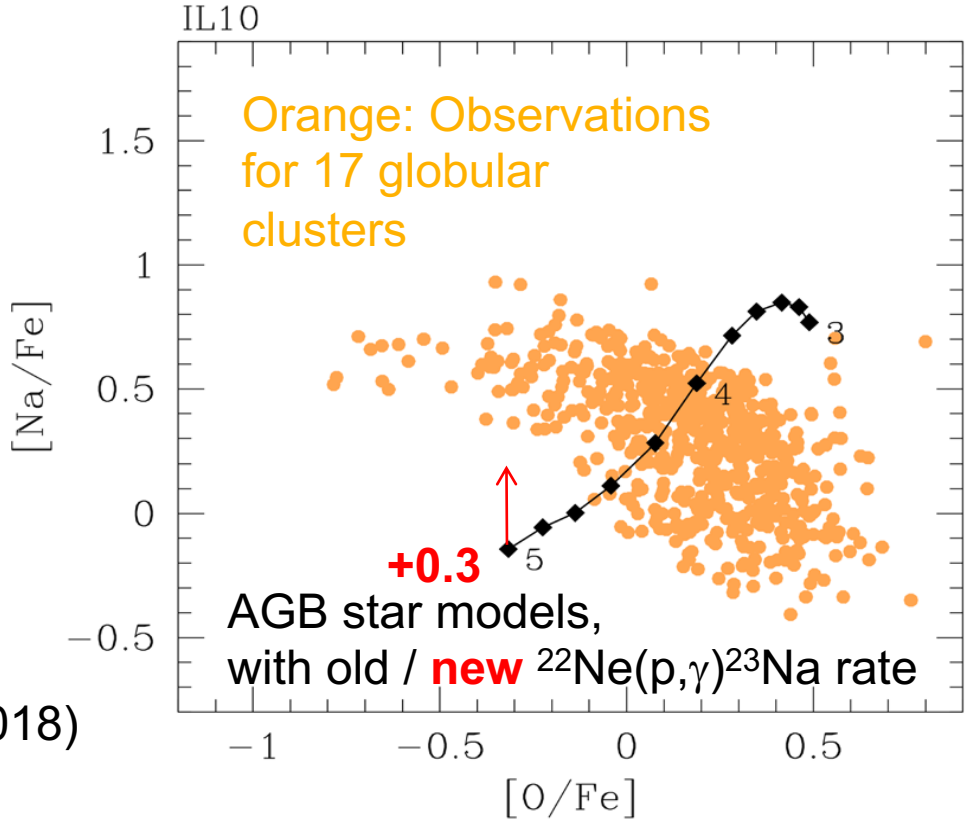
GW170817 and its kilonova
E. Pian *et al.* (2017)



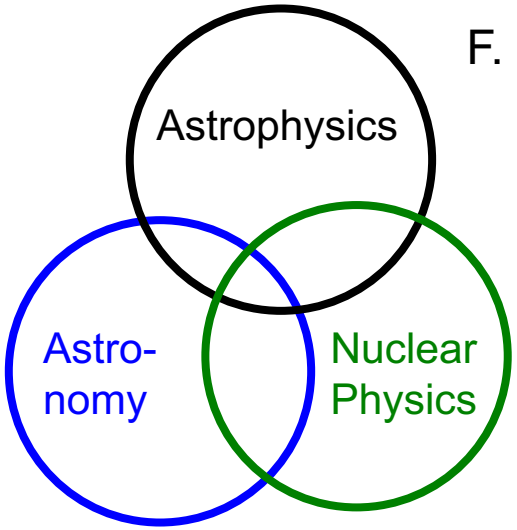
Nuclear astrophysics at the intersection of three disciplines



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

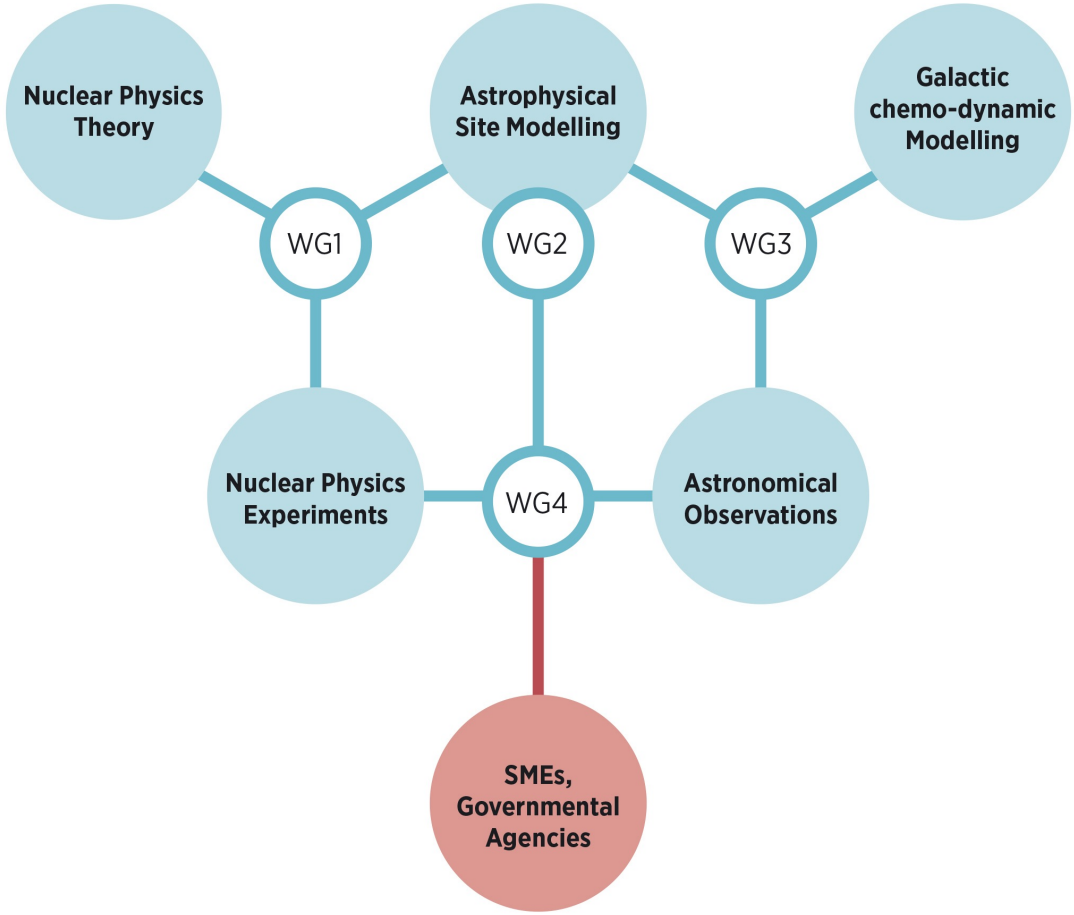
cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

http://www.chetec.eu

- ~160 k€/year 2017-2021
- 30 European countries

Chair:

- Raphael Hirschi, Keele/UK



ChETEC Action

ETEC INFRA
DRESDEN concept
HZDR

ChETEC COST action CA16117, supported meetings in calendar year 2019

Support for working group meetings

1. EC-initiated stellar collapse, Leiden/NL 20.-24.05.2019
2. Nuclear and astrophysics aspects of the rapid neutron capture process, Trento/IT, 01.-05.07.2019
3. Microphysics in Computational Relativistic Astrophysics, Jena/DE, 12.-16.08.2019
4. CEMP stars as probes of first-star nucleosynthesis, the IMF, and Galactic Assembly, Geneva/CH, 09.-13.09.2019
5. Management Committee and WG meeting co-hosted with Nuclear Physics in Astrophysics IX conference, Mainz/DE 19.09.2019
6. Toward a comprehensive and statistically meaningful $^{18}F(p,\alpha)^{15}N$ reaction rate, Orsay/FR 14.-15.10.2019
7. ChETEC follow-up in H2020 and HORIZON Europe programs, Dresden/DE 11.-12.2019
8. Lithium in the Universe: To Be or not to Be, Rome/IT 18.-22.11.2019

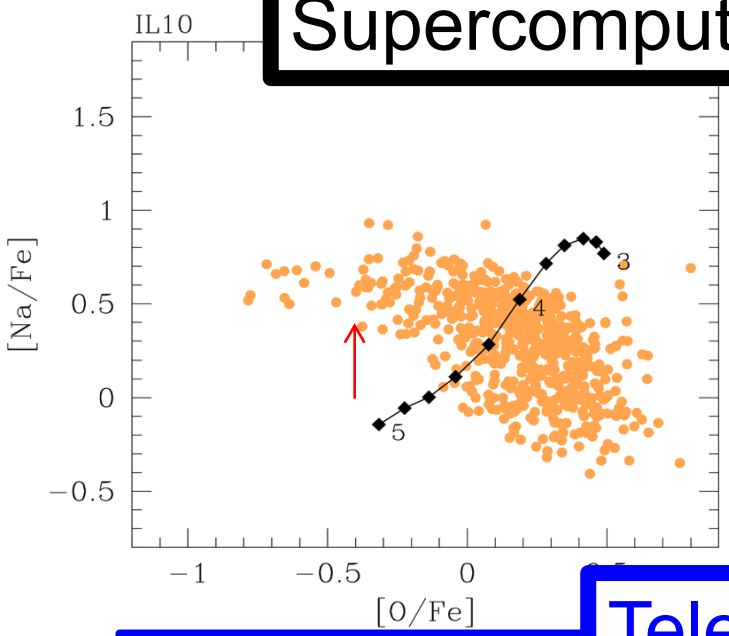
Support for Training schools

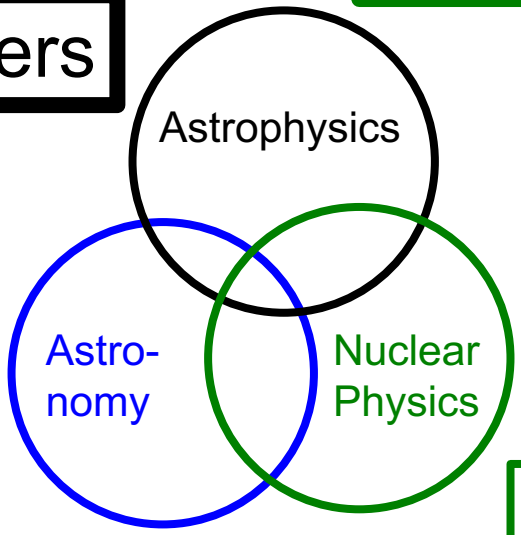
1. 55th Karpacz Winter School of Theoretical Physics and ChETEC Training School „Nuclear Astrophysics in the Multi-Messenger Area“, Karpacz/PL 24.02. – 02.03.2019
2. Direct nuclear reaction measurements (Training School), Paris/FR 08.-10.12.2019

Nuclear astrophysics, the three types of infrastructures needed for progress

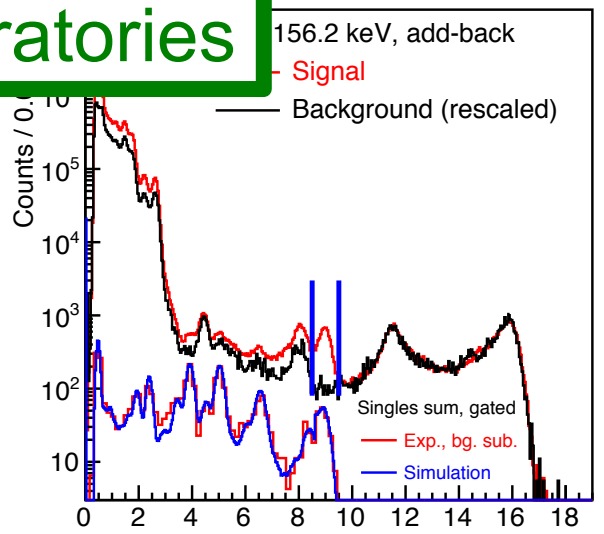
Astrophysics:
Models of asymptotic giant branch stars including $^{22}Ne(p,\gamma)^{23}Na$ nuclear reaction rate
Slemer+ 2017

Supercomputers





Nuclear laboratories



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

Telescopes

Astronomy:
Observed ^{23}Na and oxygen abundances in globular cluster stars
Carretta+ 2009

Nuclear astrophysics as an emerging field in Europe

- COST Action ChETEC
  Chemical Elements as Tracers of the Evolution of the Cosmos
  30 European countries represented
  April 2017 – October 2021
  Forerunner of ChETEC-INFRA

- Nuclear Physics in Astrophysics Conference series, since 2002
  Sponsored by the Nuclear Physics Division of the European Physical Society
  200+ participants
  2019 Mainz / Germany
  next: CERN Geneva
  Partner with ChETEC-INFRA to support NPA conference schools

- Nuclei in the Cosmos conference series, every even year since 1990
  International conference alternates between Europe and non-European countries
  200+ participants
  2021 (!!) Chengdu / China

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 agenda
  - 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
Infrastructure **access** • 8 nuclear labs • 4 telescopes • 1 computer	Infrastructure **usability** • Targets • Neutron detectors • Abundance corrections • Analysis pipelines	Infrastructure **networking** • Complementary Experiments • Solar fusion+model • Geochemistry/Astrophysics • Nuclear astrophysics schools • Outreach
32 partners, 17 countries, largest EU project for nuclear astrophysics yet		

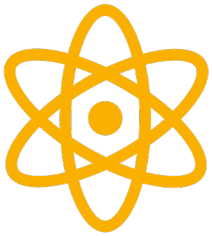
First pillar: TA Transnational Access to Research Infrastructures

★ 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

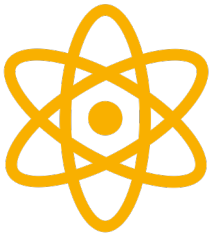
- 172 observation nights access
- IANAO Rozhen NAO 2m telescope, ***Bulgaria***
- ASU Perek 2m Telescope, ***Czech Republic***
- Aarhus University NOT Telescope La Palma, ***Spain***
- Vilnius University Molėtai Observatory, ***Lithuania***

First pillar: TA Transnational Access to Research Infrastructures

- **Astronuclear High Performance Computing**
- **Astronuclear Laboratories**
- **Astronuclear Telescopes**

Who can apply?

- Any scientist, from inside or outside the EU, from inside or outside the project, can apply
- Evaluation by an independent User Selection Panel, based on scientific excellence only
- Users must promise to publish their results

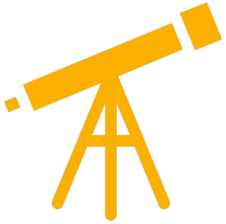


Support given

- EU funds the beam time / observation time / computational effort
- Limited support for travel to the infrastructure

When and where to apply

- Four deadlines per year, next one 17 August
- Evaluation takes 2-3 months
- `https://www.chetec-infra.eu`



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 COST action

30 countries

100 additional institutions

500 additional scientists

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)

WP3/JRA1 Astronuclear Lab (Marco La Cognata, INFN)

Task 3.1 Solid Targets for Astrophysics Research
- Roberta Spartà (INFN LNS Catania)
- ultra-pure material targets
- Implanted noble-gas targets

Task 3.2 Gas Targets for Astrophysics Research
- Tamás Szücs (ATOMKI Debrecen)
- Windowless gas target
- Gas cell targets

Task 3.3 Neutron Detector Development
- JJ Valiente Dobón (INFN LNL Legnaro)
- Scintillator-based neutron detector materials, detectors, and readout

Task 3.4 Chemical Element Sensitive Accelerator Mass Spectrometry
- Robin Golser (Vienna University, VERA AMS)
- access the nuclear charge of the isotope to be provided for AMS, e.g. by ion-gas or ion-laser-interaction
- Example case ^{182}Hf

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

WP4/JRA2 Astronuclear HPC (Marco Pignatari, Hull/UK)

Task 4.1 Stellar Nucleosynthesis Software Tools for Access to HPC
- Raphael Hirschi (Keele University, UK)
- Enable users who have stellar evolution code but are new to nucleosynthesis

Task 4.2 Nuclear Astrophysics Software Pipeline
- Marco Pignatari, Hull/UK
- Link from nuclear data to stellar nucleosynthesis
- Sensitivity studies

Task 4.3 EXNUC Explosive Nucleosynthesis Codes
- Jordi José (UPC Barcelona)
- Make stellar evolution & stellar hydro codes accessible
- Tutorials for new users, shorten training period to one month

TA HPC
- **UHULL**

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

WP5/JRA3 Astronuclear Abundances (Arunas Kucinskas, Vilnius/LT)

Task 5.1 Database of 3D NLTE Abundance Corrections

- Arunas Kucinskas (Vilnius University/LT)
- Enable analyses of stellar spectra to determine abundances
- Compute ready to use corrections using 3D hydro, relaxing assumption on local thermal equilibrium (NLTE)

Task 5.2 Homogeneous Open-Source Stellar Pipeline

- Andreas Korn (Uppsala/SE)
- Make Gaia DR2/DR3 accessible for nuclear astrophysics
- Stellar evolution corrections standardized

TA telescopes

- **ASU, AU-NOT, VU, IANAO**

JRA3 Astronuclear Abundances

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

Networking Activities (WP6 – WP9)

WP6/NA1 Comprehensive Nuclear Astrophysics (UPC Barcelona)

- 6.1 Binary Star Database (MPIA)
- 6.2 Cross-collaboration examples between disciplines (UPC)
- 6.3 Galactic chemical evolution (Hull)

NA1 Comprehensive Nucl. Astro.
- **UPC**, HZDR, ULB, MPG, HUJI, INAF, VU, CSIC, UU, UHULL

WP7/NA2 Dissemination, Outreach, Innovation (TU Dresden)

- 7.1 Nuclear Astro Masterclasses (TU Dresden)
- 7.2 Nuclear Astro Scientific Schools (GANIL)
- 7.3 Conference Outreach (HZDR)
- 7.4 Research – Industry Days (Uni Padova)

NA3 Astronuclear Library
- **CSIC**, HZDR, CNRS, IPGP, GUF, ATOMKI, INFN, UKE, UMIL

WP8/NA3 Astronuclear Library (CSIC Barcelona)

- 8.1 “Big Three” nuclear reactions: $^{12}C(\alpha,\gamma)$, $^{12}C+^{12}C$, $^{22}Ne(\alpha,n)$ (Catania)
- 8.2 Solar fusion and solar models (CSIC)
- 8.3 Reaction rate library (Frankfurt)
- 8.4 Web page, data, metadata (Frankfurt)

NA2 Dissemination/Outreach/Innovation
- **TUD**, HZDR, CNRS, GANIL, GUF, INFN, UNIPD, VU, IFIN-HH, UU, KEELE, UHULL

WP9/NA4 Mass Spectrometry (Konkoly Budapest)

- Network nuclear astrophysics and geochemistry communities
- Mass spectrometry (without and with accelerator)

NA4 Mass Spectrometry Network
- **CSFK**, HZDR, UNIVIE, IPGP, ETHZ, UHULL

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*)

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 partipants

Increase participation across Europe+, across genders, nationalities, …

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

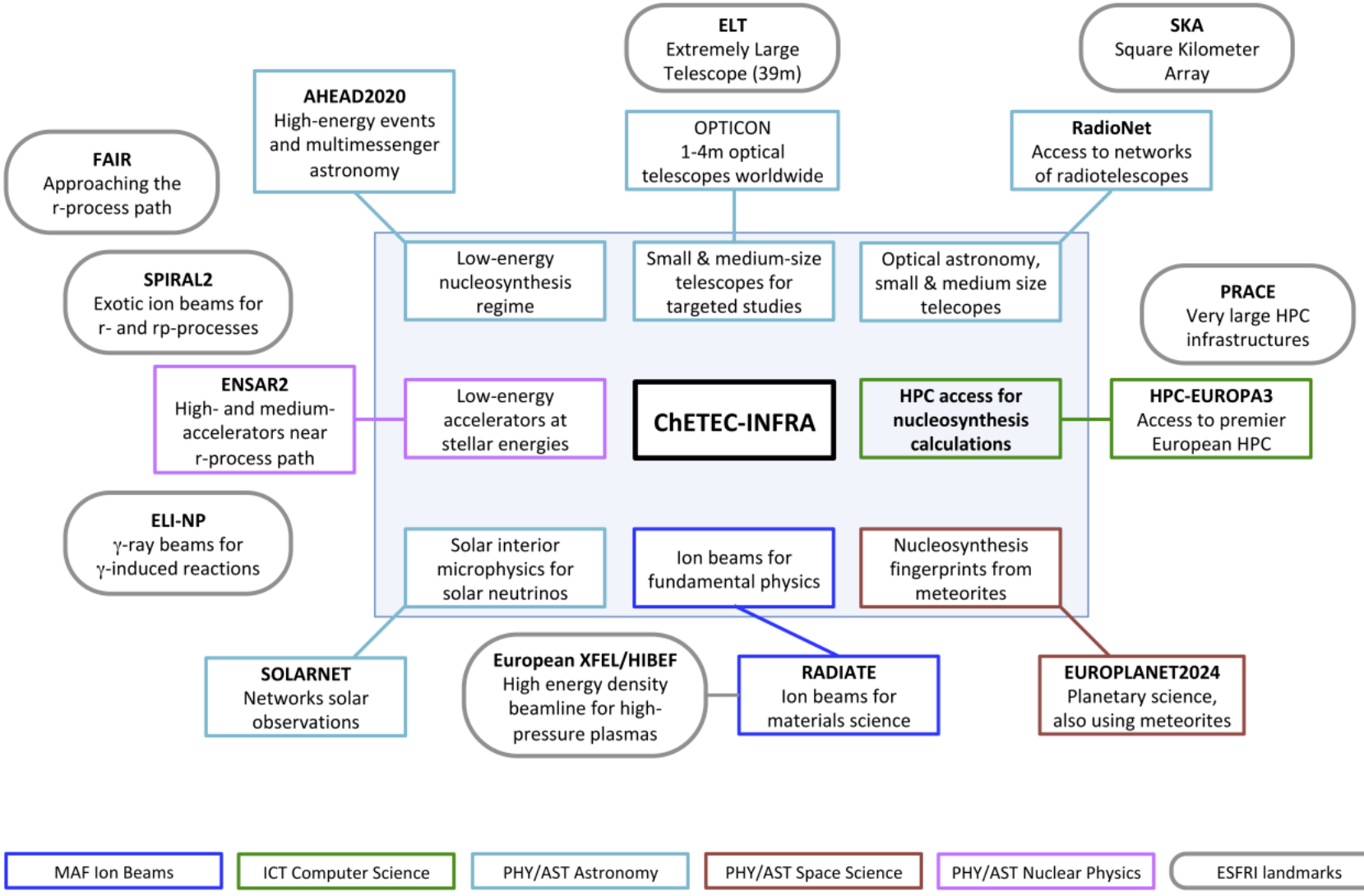
Synergies and coherence with neighboring communities

- 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, ...

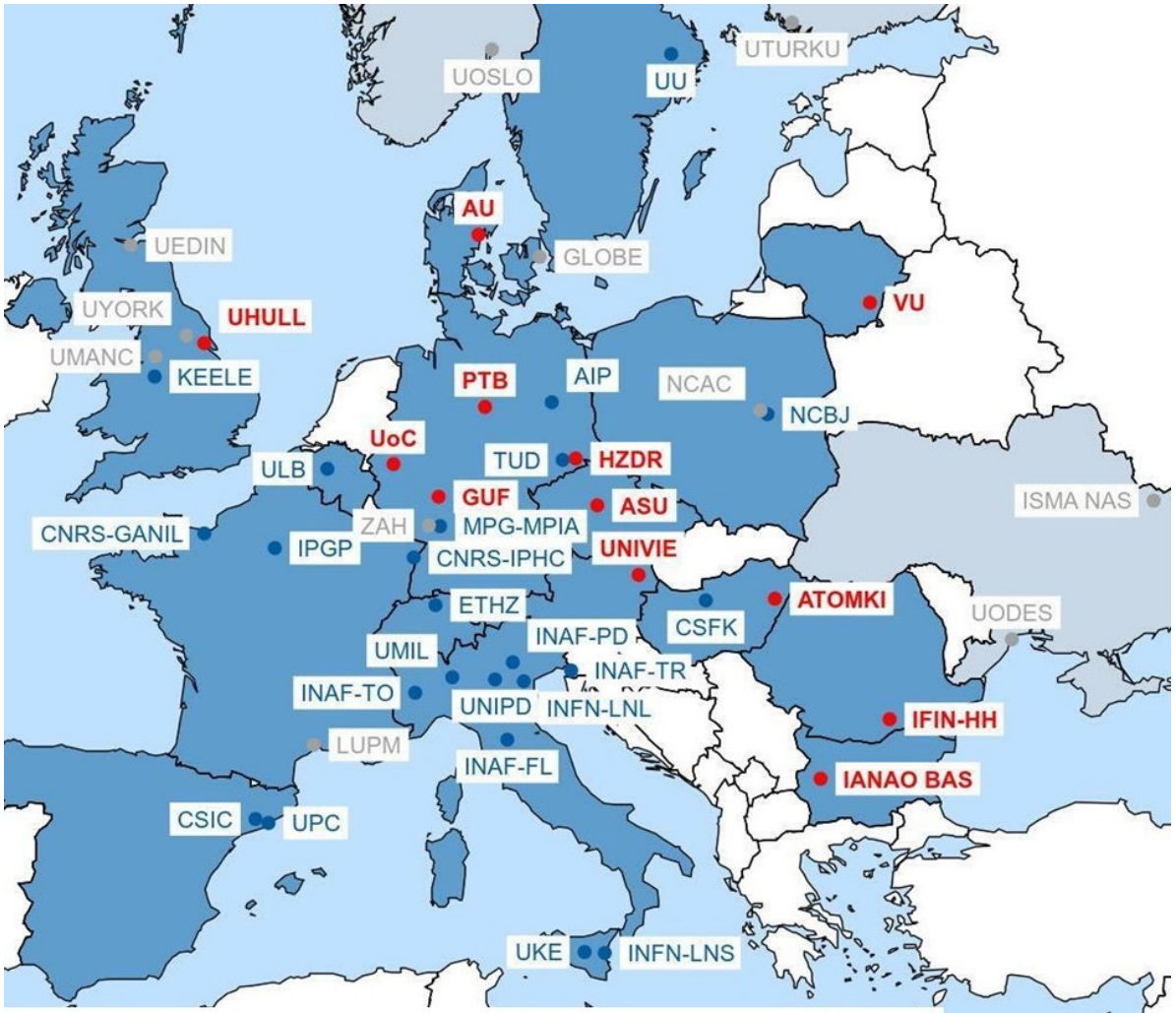
Interdisciplinary approaches

- 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 and other EU infrastructure initiatives



ChETEC-INFRA, 32 partners in 17 countries



- **ChETEC-INFRA partners with TA infrastructures**
- ChETEC-INFRA other funded partners
- ChETEC-INFRA associated partners

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**

What does it already mean for you?

- Network of research infrastructures to **serve** nuclear astrophysics
- ChETEC-INFRA access to research infrastructures is **open to all** scientists, selection based on scientific merit