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

WP6/NA1
“Comprehensive Nuclear Astrophysics”

ChETEC-INFRA General Assembly 2025

Jordi José, UPC Barcelona, jordi.jose@upc.edu, chetec-infra.eu

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Aims

- Link three types of nuclear astrophysics infrastructures to one model science case: the astrophysical s-process: AGB stars observed by means of ChETEC-INFRA telescopes are then modeled by ChETEC-INFRA HPC, and selected uncertain nuclear reactions be studied at ChETEC-INFRA nuclear labs

- Plan of action through textbook examples of cross-collaboration between astronomers, astrophysicists, nuclear physicists and cosmochemists

- State-of-the-art yields from all astrophysical sites that contribute to galactic nucleosynthesis will be merged into a brand-new, user-friendly galactic chemical evolution (GCE) platform

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Structure

WP6 Coordination: Jordi José, UPC Barcelona

Task 6.1 Binary Star Database to support observations
(PI: Camilla J. Hansen, U Frankfurt, & Richard Stancliffe [now at U Bristol]; other participants: MPIA Heidelberg, U Hull, VU Vilnius, IANAO Bulgaria, ASU Czech Republic)

Task 6.2 Cross-Collaboration Textbook Examples
(PI: Jordi José, UPC Barcelona; other participants: HUJI Jerusalem, ULB Brussels, HZDR Dresden, U Hull, MPIA Heidelberg, VU Vilnius)

Task 6.3 Galactic Chemical Evolution
(PI: James Keegans, U Hull; other participants: CSFK Budapest, INAF Rome)

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Task 6.1 – Report on main activities

Binary Star Database to support observations

SPECIFIC GOALS

-Training students in **all** astro-nuclear-disciplines: Observations, theory, experiments – the plan was to hire a student, starting out with **observations**, and following train the student in **theory**, and **experiments** (Oslo / Frankfurt)
-**Observe AGB, Ba, CEMP-s stars**, derive RV + 1D, LTE abundances → apply corrections (in collaboration with WP5)
-**Generate grid of stellar evolution models & binary accretion** (AGB + s-process)
-**Experiments relevant for the s-process** (cross sections for Bi & Pb at low energies)

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Task 6.1 – Report on main activities

Binary Star Database to support observations

MAIN ACTIVITIES PERFORMED AND ACHIEVEMENTS

To understand binary systems, mass transfer, AGB stars, and the s-process that they host, we carried out binary monitoring through repeated radial velocity (RV) observations. The s-process nucleosynthesis was explored via chemical abundance analyses of AGB and binary stars.

The current state of the RV part by number is:
(i) Total observing nights awarded: **188** at TNA telescopes: Moletai, Ondrejov, and Rozhen
(ii) Total number of stars observed: **404**
(iii) Total number of RVs measured: **>1600**
Approximate average RV_{rms}: ~2 km/s (best ≤ 0.1 km/s) at TNA telescopes which is comparable to literature RV_{rms} which typically cover a similar range ~ 0.05 – 3 km/s

Task 6.1 – Report on main activities

Binary Star Database to support observations

MAIN ACTIVITIES PERFORMED AND ACHIEVEMENTS

The current state of the abundance part by number is:
(i) Total number of stars with estimated atmospheric parameters: **312**
(ii) Total number of stellar abundances/patterns computed: **30**
Target stars are observed at TNA facilities with high- resolution echelle spectrographs at a moderate signal-to-noise (S/N) for RVs and high S/N for abundances.

Raw spectra are reduced using observatory pipelines and our own codes. Targets are prioritized for follow-up to build the RV database. Stellar parameters are estimated using the ATHOS code, and are found generally in agreement with the literature. 1D-LTE atmospheres are interpolated from MARCS and ATLAS models. Photospheric abundances are computed using MOOG. For desired s-process elements, abundances from clean lines are computed using Gaussian profiles, and abundances from blended lines are computed using spectral synthesis.

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Task 6.1 – Report on main activities

Binary Star Database to support observations

OUTCOMES

Outreach activities: We have participated in several local and virtual events (e.g., SNAQs, MPIA OuterSpace, MPIA Open Day)

Deliverables (Task 6.1, Month 48): **D6.1** completed. Astronuclear spectral database hosted on Zenodo, see presentation by Alex. Database contains raw and reduced spectral data, measured stellar RVs, estimated atmospheric parameters, and derived abundances of s-process elements.

Publications: 2 published (Dimoff et al. 2024, 2025), 1 in preparation

Talks in Conferences/Workshops/Schools: ~12

WP6/NA1 "Comprehensive Nuclear Astrophysics"

Task 6.2 – Report on main activities

Cross-Collaboration Textbook Examples

SPECIFIC GOALS

Provide the ChETEC-INFRA community with **textbook examples** of cross-collaboration between astronomers, astrophysicists, nuclear physicists, and cosmochemists.

(i) **Identification of suitable science cases** (i.e., nuclear reactions of astrophysical interest affected by large nuclear uncertainties) through **sensitivity studies**
(ii) **Feasibility studies** of the nuclear physics experiments planned to reduce their associated uncertainties
(iii) Preparation of a **proposal for the experiment**
(iv) **Measurement and data analysis**
(v) Evaluation of the **astrophysical/cosmochemical impact** for a specific stellar site

WP6/NA1 "Comprehensive Nuclear Astrophysics"

Sensitivity studies → Identification of key reactions of astrophysical interest → Experiments

The Astrophysical Journal Supplement Series, 178:110–136, 2008 September

THE EFFECTS OF VARIATIONS IN NUCLEAR PROCESSES ON TYPE I X-RAY BURST NUCLEOSYNTHESIS

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Jordi José
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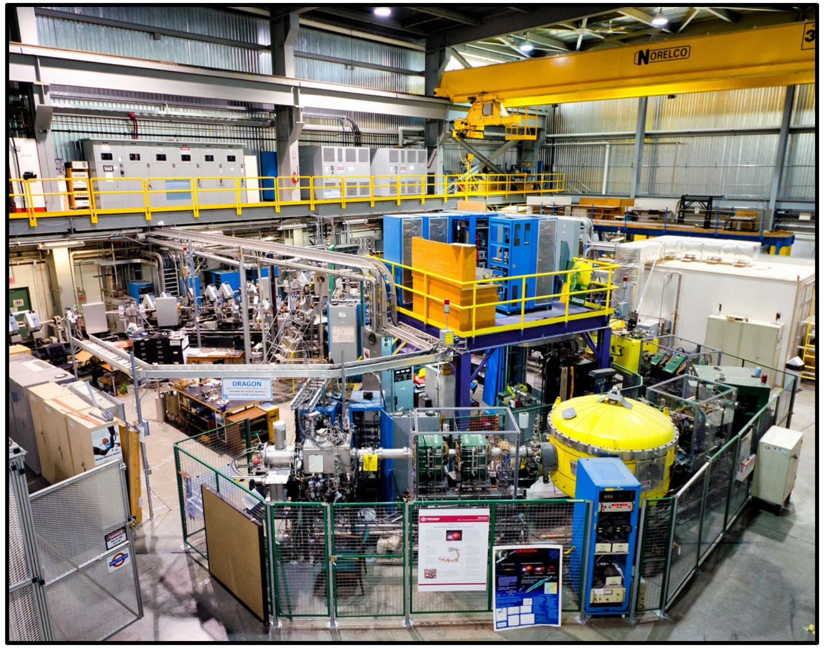
Fermín Moreno
Departament de Física i Enginyeria Nuclear, EUETIB, Universitat Politècnica de Catalunya, E-08036 Barcelona, Spain; moreno@ieec.fcr.es
and
Christian Iliadis
Department of Physics and Astronomy, University of North Carolina, Chapel Hill, NC 27599-3255; and Triangle Universities Nuclear Laboratory, Durham, NC 27708-0308; iliadis@unc.edu

TABLE 20
Nuclear Processes Affecting the Total Energy Output by More than 5% and at Least One Isotope

Reaction	Models Affected
^{15}O(α, γ)^{19}Ne[a]	K04, K04-B1, K04-B6
^{18}Ne(α, p)^{21}Na[a]	K04-B1, K04-B6
^{22}Mg(α, p)^{25}Al	F08
^{23}Al(p, γ)^{24}Si	K04-B1
^{24}Mg(α, p)^{27}Al[a]	K04-B2
^{26g}Al(p, γ)^{27}Si[a]	F08
^{28}Si(α, p)^{31}P[a]	K04-B4
^{30}S(α, p)^{33}Cl	K04-B4, K04-B5
^{31}Cl(p, γ)^{32}Ar	K04-B3
^{32}S(α, p)^{35}Cl	K04-B2
^{35}Cl(p, γ)^{36}Ar[a]	K04-B2
^{56}Ni(α, p)^{59}Cu	S01
^{59}Cu(p, γ)^{60}Zn	S01
^{65}As(p, γ)^{66}Se	K04, K04-B2, K04-B3
^{69}Br(p, γ)^{70}Kr	S01
^{71}Br(p, γ)^{72}Kr	K04-B7
^{103}Sn(α, p)^{106}Sb	S01

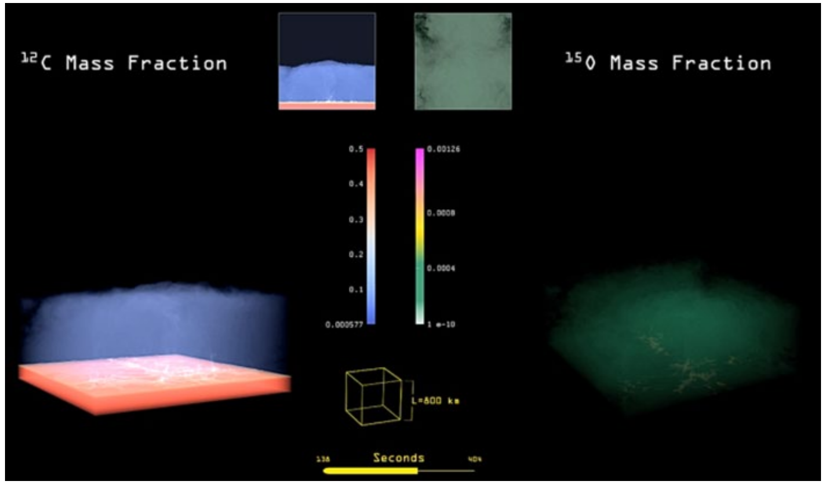


PHYSICAL REVIEW LETTERS 128, 182701 (2022)

Constraining the ^{30}P(p,γ)^{31}S Reaction Rate in ONe Novae via the Weak, Low-Energy, β-Delayed Proton Decay of ^{31}Cl

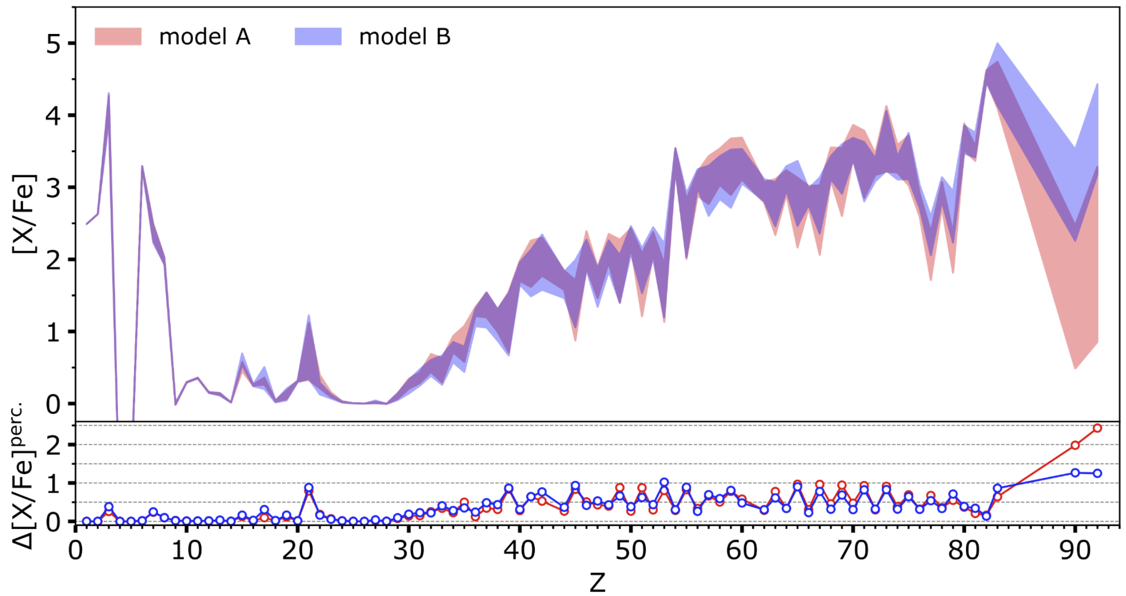
T. Budner,[1,2,*] M. Friedman,[1,3] C. Wrede,[1,2,†] B. A. Brown,[1,2] J. José,[4,5] D. Pérez-Loureiro,[1] L. J. Sun,[1,6] J. Surbrook,[1,2] Y. Ayyad,[1,7] D. W. Bardayan,[8] K. Chae,[9] A. A. Chen,[10] K. A. Chipps,[11,12] M. Cortesi,[1] B. Glassman,[1,2] M. R. Hall,[8] M. Janasik,[1,2] J. Liang,[10] P. O'Malley,[8] E. Pollacco,[13] A. Psaltis,[10] J. Stomps,[1,2] and T. Wheeler[1,2]

Astrophysical impact of new reaction rates

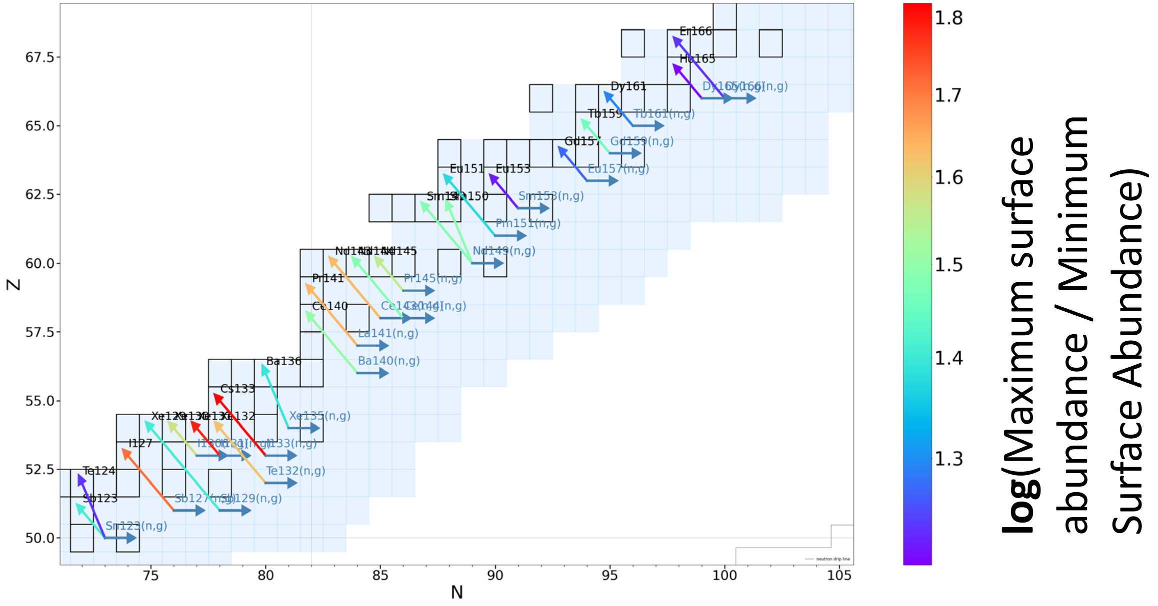


WP6/NA1 "Comprehensive Nuclear Astrophysics"

Sensitivity studies → Identification of key reactions of astrophysical interest → Experiments



Correlated models uncertainties and Non-correlated parameters uncertainties in early AGB stars



Identification of key (n,g) reactions for the i-process nucleosynthesis

S. Martinet, S. Goriely, ULB Brussels

Task 6.2 – Report on main activities

Cross-Collaboration Textbook Examples

MAIN ACTIVITIES PERFORMED AND ACHIEVEMENTS

We have selected a small set of key reactions previously identified in existing sensitivity studies:

(1) $^{30}P(p,\gamma)$, relevant for classical novae

(2) $^{15}O(\alpha,\gamma)$, relevant for type I X-ray bursts

(3) $^{26}Al(n,p)$ and $^{26}Al(n,\alpha)$, relevant for core-collapse supernovae.

The impact of the new reaction rates has been evaluated with state-of-the-art stellar codes developed and maintained in WP6. PhD Students and young Postdocs have actively participated in all the different stages mentioned above, getting in turn training in computational astrophysics, observational astronomy, experimental nuclear physics, and cosmochemistry.

WP6/NA1 "Comprehensive Nuclear Astrophysics"

Other examples of cross-collaboration

PHYSICAL REVIEW C **108**, 035807 (2023)

Confirmation of a new resonance in ^{26}Si and contribution of classical novae to the galactic abundance of ^{26}Al

L. Canete,[1,*] D. T. Doherty,[1] G. Lotay,[1] D. Seweryniak,[2] C. M. Campbell,[3] M. P. Carpenter,[2] W. N. Catford,[1] K. A. Chipps,[4] J. Henderson,[1] R. G. Izzard,[1] R. V. F. Janssens,[5,6] H. Jayatissa,[2] J. José,[7,8] A. R. L. Kennington,[1] F. G. Kondev,[2] A. Korichi,[2,9] T. Lauritsen,[2] C. Müller-Gatermann,[2] C. Paxman,[1] Zs. Podolyák,[1] B. J. Reed,[1] P. H. Regan,[1,10] W. Reviol,[2] M. Siciliano,[2] G. L. Wilson,[2,11] R. Yates,[1] and S. Zhu[12,†]

PHYSICAL REVIEW C **108**, L052801 (2023)

Letter

First measurement of the low-energy direct capture in ^{20}Ne$(p,\gamma)^{21}$Na and improved energy and strength of the $E_{c.m.} = 368$ keV resonance

E. Masha,[1,2,3] L. Barbieri,[4,5] J. Skowronski,[4,5] M. Aliotta,[6] C. Ananna,[7,8] F. Barile,[9,10] D. Bemmerer,[1] A. Best,[7,8] A. Boeltzig,[1] C. Broggini,[5] C. G. Bruno,[6] A. Caciolli,[4,5,*] M. Campostrini,[11] F. Casaburo,[12,13] F. Cavanna,[14] G. F. Ciani,[9,10] A. Ciapponi,[2,3] P. Colombetti,[15,14] A. Compagnucci,[16,17] P. Corvisiero,[12,13] L. Csedreki,[18] T. Davinson,[6] R. Depalo,[2,3] A. Di Leva,[7,8] Z. Elekes,[18] F. Ferraro,[2,3] E. M. Fiore,[9,10] A. Formicola,[19] Zs. Fülöp,[18] G. Gervino,[15,14] A. Guglielmetti,[2,3] C. Gustavino,[19] Gy. Gyürky,[18] G. Imbriani,[7,8] J. José,[20,21] M. Junker,[17] M. Lugaro,[22,23] P. Manoj,[14] P. Marigo,[4,5] R. Menegazzo,[5] V. Paticchio,[10] D. Piatti,[4,5] P. Prati,[12,13] D. Rapagnani,[7,8] V. Rigato,[11] D. Robb,[6] L. Schiavulli,[9,10] R. S. Sidhu,[6] O. Straniero,[24,19] T. Szücs,[18] and S. Zavatarelli[12,13,†]
(LUNA collaboration)

nature communications

Article https://doi.org/10.1038/s41467-023-40121-3

Search for ^{22}Na in novae supported by a novel method for measuring femtosecond nuclear lifetimes

Chloé Fougères[1,2], François de Oliveira Santos[1], Jordi José[3,4], Caterina Michelagnoli[1,5], Emmanuel Clément[1], Yung Hee Kim[1,6], Antoine Lemasson[1], Valdir Guimarães[7], Diego Barrientos[8], Daniel Bemmerer[9], Giovanna Benzoni[10], Andrew J. Boston[11], Roman Böttger[9], Florent Boulay[1], Angela Bracco[10], Igor Čeliković[12], Bo Cederwall[13], Michał Ciemala[14], Clément Delafosse[15], César Domingo-Pardo[16], Jérémie Dudouet[17], Jürgen Eberth[18], Zsolt Fülöp[19], Vicente González[20], Andrea Gottardo[21], Johan Goupil[1], Herbert Hess[18], Andrea Jungclaus[22], Ayşe Kaşkaş[23], Amel Korichi[15], Silvia M. Lenzi[24,25], Silvia Leoni[10,26], Hongjie Li[1], Joa Ljungvall[15], Araceli Lopez-Martens[15], Roberto Menegazzo[24], Daniele Mengoni[24,25], Benedicte Million[10], Jaromír Mrázek[27], Daniel R. Napoli[21], Alahari Navin[1], Johan Nyberg[28], Zsolt Podolyák[29], Alberto Pullia[10,26], Begoña Quintana[30], Damien Ralet[1,15], Nadine Redon[17], Peter Reiter[18], Ksenia Rezynkina[24,31], Frédéric Saillant[1], Marie-Delphine Salsac[32], Angel M. Sánchez-Benítez[33], Enrique Sanchis[20], Menekşe Şenyiğit[23], Marco Siciliano[2,32], Nadezda A. Smirnova[34], Dorottya Sohler[19], Mihai Stanoiu[35], Christophe Theisen[32], Jose J. Valiente-Dobón[21], Predrag Ujić[12] & Magdalena Zielińska[32]

Nature Communications | (2023)14:4536

Other examples of cross-collaboration

Astronomy & Astrophysics manuscript no. output
March 25, 2024

Thermonuclear ^{28}P$(p, \gamma)^{29}$S reaction rate and astrophysical implication in ONe nova explosion

J.B. Liu[1,2], J. José[3,4], S.Q. Hou[1,2,5], M. Pignatari[5,6,7,8,9], T. C. L. Trueman[5,6,7,8], R. Longland[10,11], J.G. Li[1,2], C. A. Bertulani[12], and X.X. Xu[1,2]

Astron. Astrophys. 687, A199, July 2024

First study of the ^{139}Ba(n,γ)^{140}Ba reaction to constrain the conditions for the astrophysical i process

A. Spyrou,[1,2,3,*] D. Mücher,[4,5,6,†] P.A. Denissenkov,[7,8] F. Herwig,[7,8] E. C. Good,[1,3] G. Balk,[9] H.C. Berg,[1,2,3] D. L. Bleuel,[10] J.A. Clark,[11] C. Dembski,[1,2,3] P.A. DeYoung,[9] B. Greaves,[5] M. Guttormsen,[12] C. Harris,[13,2,3] A.C. Larsen,[12] S. N. Liddick,[1,14] S. Lyons,[15] M. Markova,[12] M.J. Mogannam,[1,14] S. Nikas,[16] J. Owens-Fryar,[1,2,3] A. Palmisano-Kyle,[17] G. Perdikakis,[18] F. Pogliano,[12] M. Quintieri,[1,2] A. L. Richard,[10] D. Santiago-Gonzalez,[11] G. Savard,[11] M.K. Smith,[1,3] A. Sweet,[10] A. Tsantiri,[1,2,3] and M. Wiedeking[19,20]

Phys. Rev. Letters 132, 202701, May 2024

Task 6.2 – Report on main activities

Cross-Collaboration Textbook Examples

OUTCOMES

Outreach activities: multiple outreach activities have been conducted by participants of Task 6.3, including “Seminar at SNAQs”, “Public Talk at INPC22, Cape Town”.

Deliverables (Task 6.2, Month 12): **D6.2**. We published on ChETEC-INFRA webpage a first version of the multidisciplinary guide to astronuclear science cases. It includes a discussion on the role of sensitivity studies in the identification of key reactions (and in the evaluation of the impact of their uncertainties), and a number of specific astrophysical scenarios in explosive nucleosynthesis for which such sensitivity studies have been conducted (e.g., novae and supernovae, X-ray bursts...).

Publications: ~15

Talks in Conferences/Workshops/Schools: ~10

Task 6.3 – Report on main activities

Galactic Chemical Evolution

SPECIFIC GOALS

- Development of the **next generation of the OMEGA/OMEGA+ software pipeline**, linking GCE expertise at Hull, with those at CSFK and INAF. These subtasks include:

  *__Multi-zone extension__ to the existing single-zone versions of both codes
  **__Radial gas flows__

- Maintenance of (i) **stellar yields databases**, and (ii) **stellar observational abundances databases**; integration with OMEGA/OMEGA+

Task 6.3 – Report on main activities

Galactic Chemical Evolution

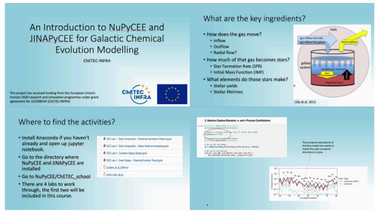
MAIN ACTIVITIES PERFORMED AND ACHIEVEMENTS

The primary goal has been the development of the next generation of the OMEGA/OMEGA+ software pipeline, linking Galactic Chemical Evolution expertise at UHull, with those at CSFK and INAF. Among the achievements obtained:

- A framework for the multi-zone extension to the existing version of OMEGA/OMEGA+ has been developed.
- The multi-zone framework includes a prescription for radial gas flows.
- PhD student attached to 6.3 has published a first-author paper using the OMEGA tools (Womack et al. 2023)

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Galactic Chemical Evolution Modelling



A video course on GCE Modelling with NuPyCEE and JINAPyCEE that guides through the initial setup, and their application in two lab projects.

The course can be found on this page.

What did you like about this session?

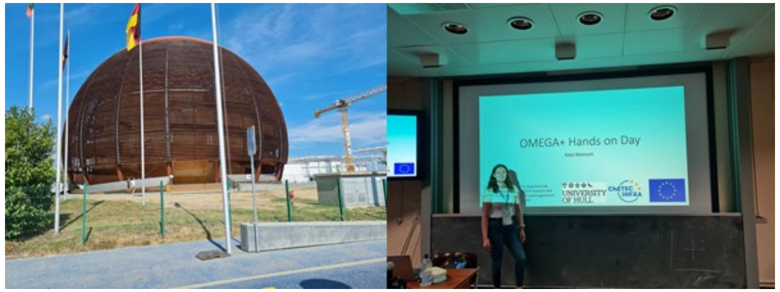
- The jupyter notebook format was helpful for the participants to visualise the concepts.
- Participants enjoyed the hands-on way of learning and liked how interactive the session felt.
- Participants enjoyed that the knowledge was gradually built up over the course of the session.
- Participants enjoyed the enthusiastic presenting style and the explainers of the main concepts of before starting each task.

Do you feel able to use OMEGA+ for basic chemical evolution modelling after this session?

Yes = 17

Somewhat = 9

No = 3



- Both GCE courses are now on the ChETEC-INFRA webpage.
- Two in-person training events have been delivered (KW).
  - NPA-X school – September 2022
  - STFC Astronomy Summer School – September 2023
- Total number of trained users through these courses: 107
- Training session delivered to 2nd Frontiers in Nuclear Astrophysics Summer School training ~50 PhD students

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Task 6.3 – Report on main activities

Galactic Chemical Evolution

OUTCOMES

Outreach activities: 211 outreach events between May 2021 and Oct 2022. Since October 2022, there have been a variety of outreach events carried out, including: 2 talks at astronomical societies, 3 *Pint of Science,* and several visits to local schools and colleges.

Deliverables
D6.3. We launched an online and in-person OMEGA/Python training school (NPA-X School).
D6.5. K. Womack reported on the uptake of web-based training courses at the 2023 ChETEC-INFRA GA.
D6.6. We have compiled a document outlining the progress towards key targets as set out in Task 6.3.

Publications: 30

Talks in Conferences/Workshops/Schools: 13 (2021 – 2025)

WP6/NA1 “Comprehensive Nuclear Astrophysics”

Milestone:

- **M11** First documented example of cross-collaboration led by an early-stage researcher from outside the consortium involving identification of a key nuclear rate, supported by elemental or isotopic abundance determinations, in the framework of astrophysical simulations (Month 36).

Deliverables:

- D6.1 Provide AGB/binary database interface on project web site with open access to all new observations to outside users (Task 6.1, Month 6)
- D6.2 Publication on project web page of the first version of the multidisciplinary guide to astronuclear science cases (Task 6.2, Month 12)
- D6.3 First online training course active; expected 40 users-institutes per year (Task 6.3, Month 12)
- D6.4 Cross disciplinary training of a student/postdoc in all three disciplines – experiments (GUF, HZDR, and associate partner Oslo), theory (UHULL), Observations (MPG/VU) (Task 6.2; Month 24)
- D6.5 Report on uptake of web-based training courses (Task 6.3; Month 24)
- D6.6 Scientific publication (review) on NA1 results (Task 6.3, Month 36)
- D6.7 Report on uptake of web-based training courses (Task 6.3, Month 48)

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

WP6/NA1
"Comprehensive Nuclear Astrophysics"

ChETEC-INFRA General Assembly 2025

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