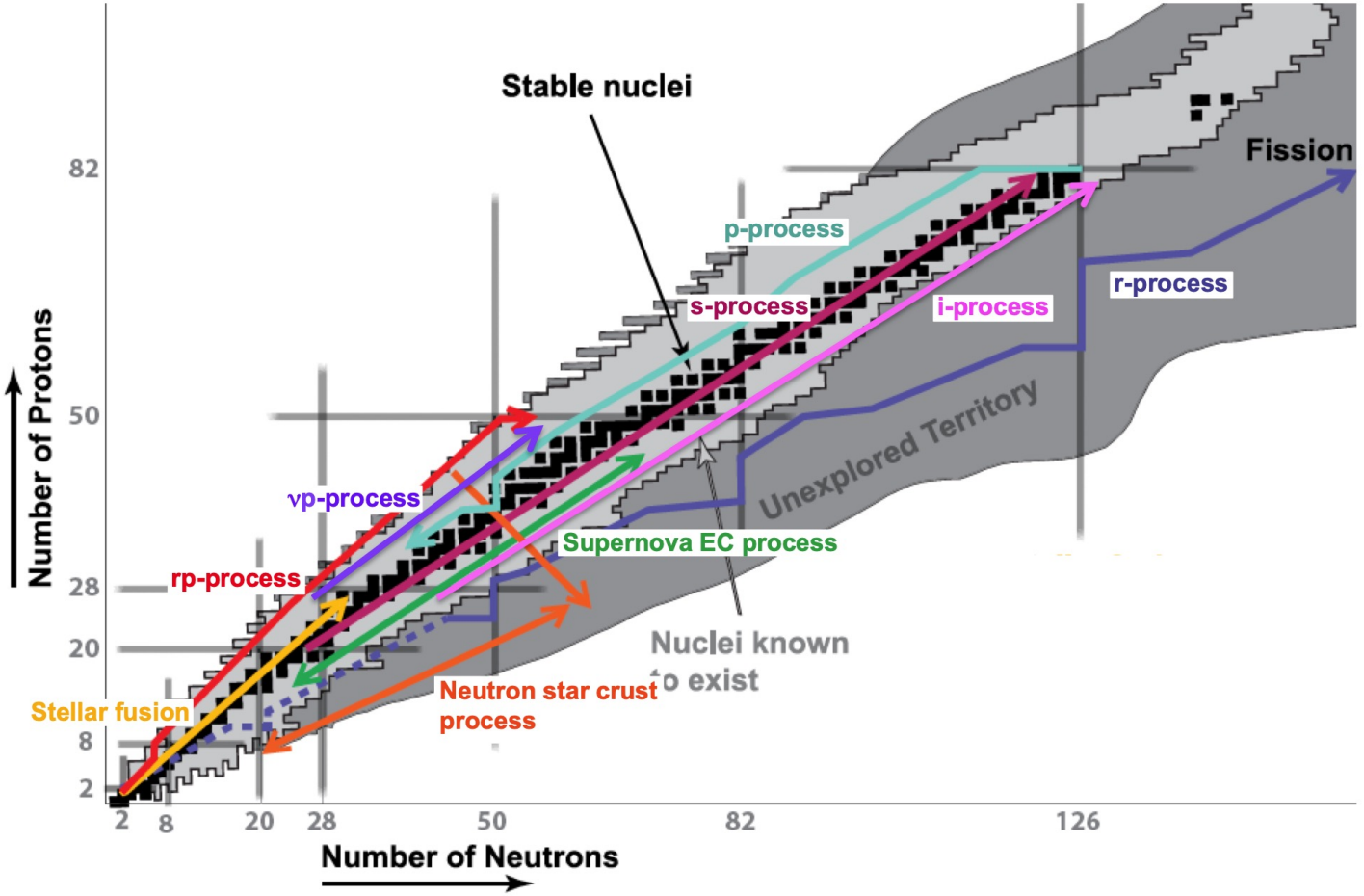
FONDAZIONE BRUNO KESSLER
ECT*
EUROPEAN CENTRE FOR THEORETICAL STUDIES IN NUCLEAR PHYSICS AND RELATED AREAS
EURO-LABS
EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES
Theory Alliance
FACILITY FOR RARE ISOTOPE BEAMS
GOBIERNO DE ESPAÑA
MINISTERIO DE ASUNTOS EXTERIORES, UNIÓN EUROPEA Y COOPERACIÓN
cnrs
Funded by the European Union

ECT* workshop on "Nuclear theory for astrophysics: bridging bound-state and continuum physics"

Pierre Arthuis, Francesca Bonaiti, Matthias Heinz, Guillaume Hupin and Saori Pastore

May 18, 2026

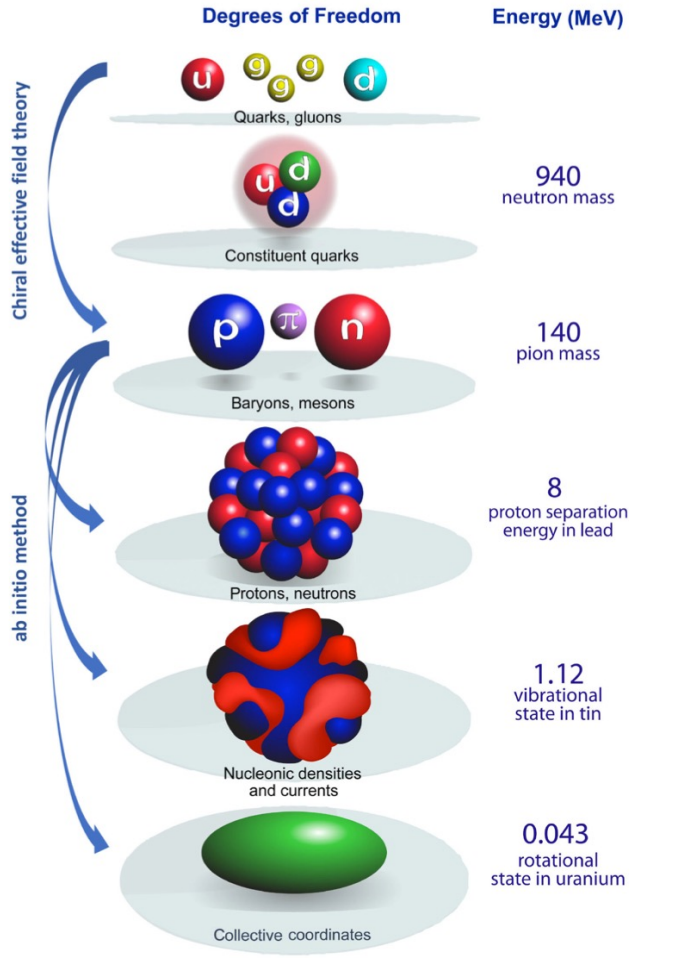
Nuclear physics is key to understand the origin of elements



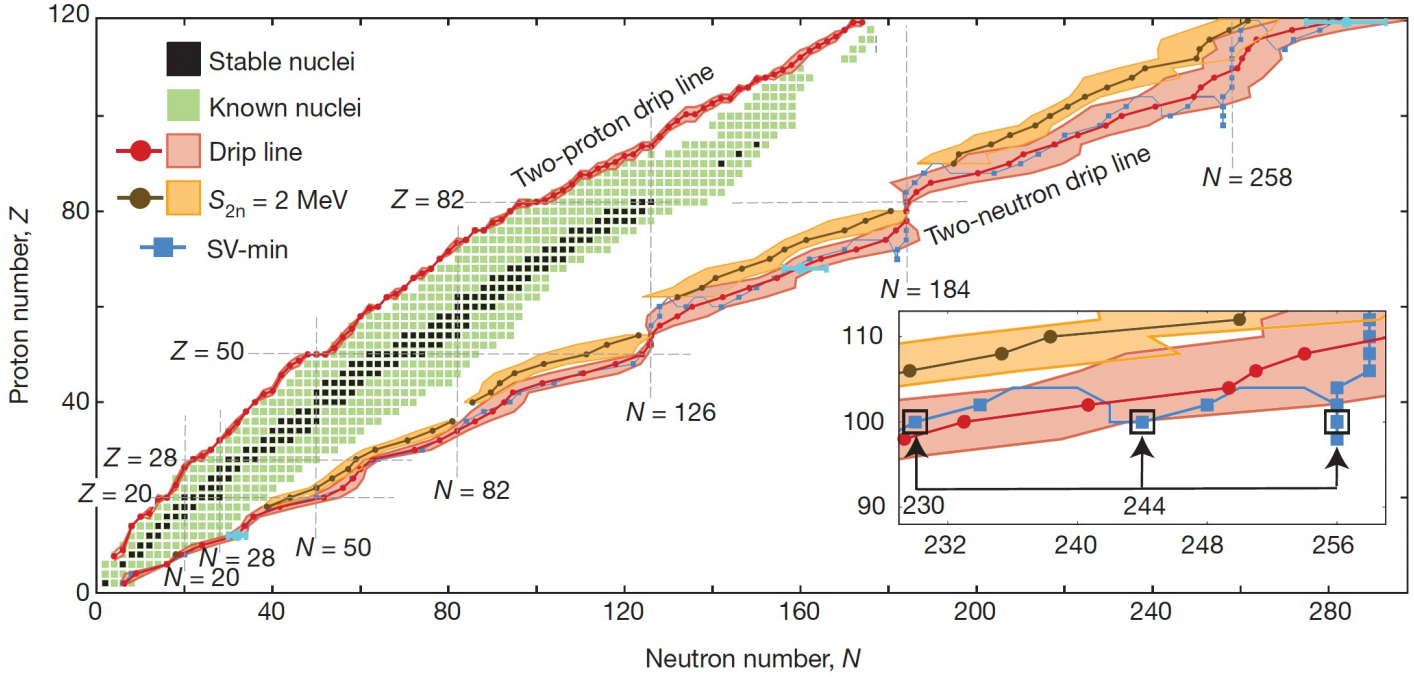
- Reaction observables are a crucial input to nucleosynthesis simulations (more in Almudena's and Artemis' talks).
- Nuclei of interest, especially for the r-process, can be challenging to reach experimentally.
- Reliable theory is required.
- Where do we stand with addressing nuclear dynamics?

Hendrik Schatz, *J. Phys. G: Nucl. Part. Phys.* **43** 064001 (2016)

Nuclear structure has seen impressive progress in the last few years

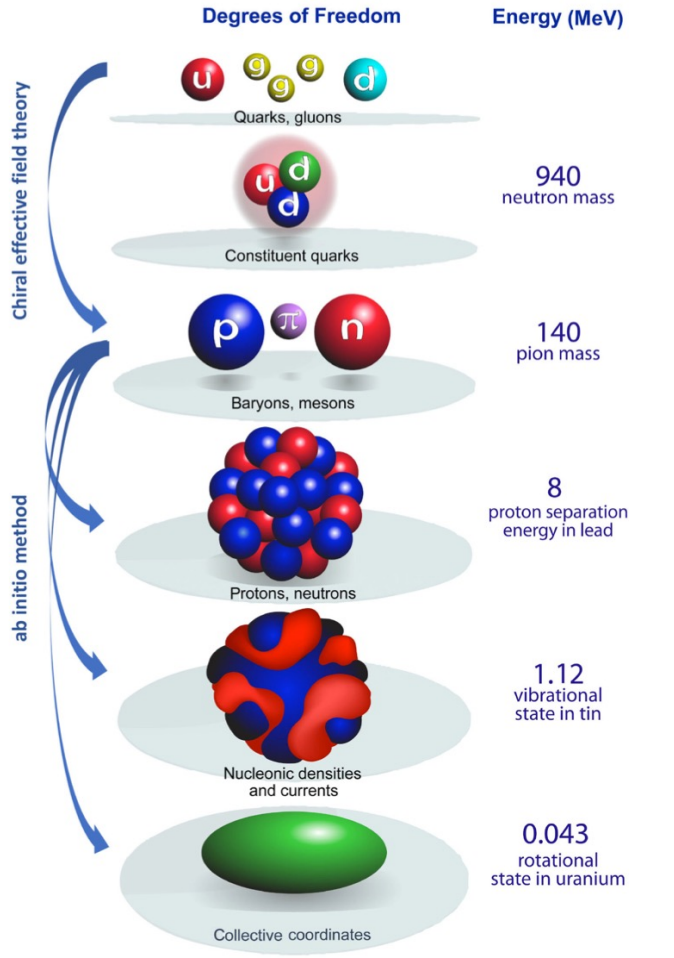


Z. Sun et al., PRX 15, 011028 (2025).

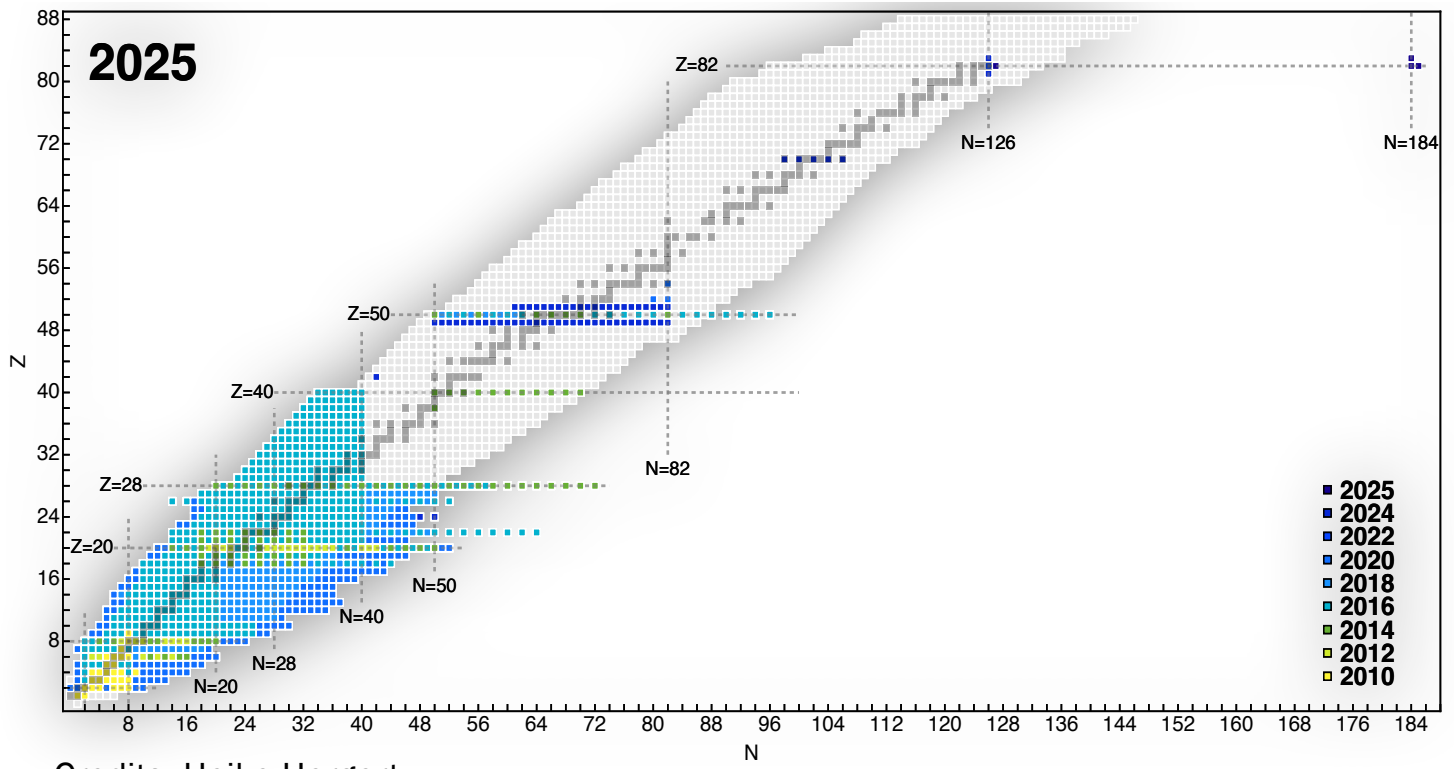


J. Erler et al, Nature 486, 1075–1079 (2012).

Nuclear structure has seen impressive progress in the last few years

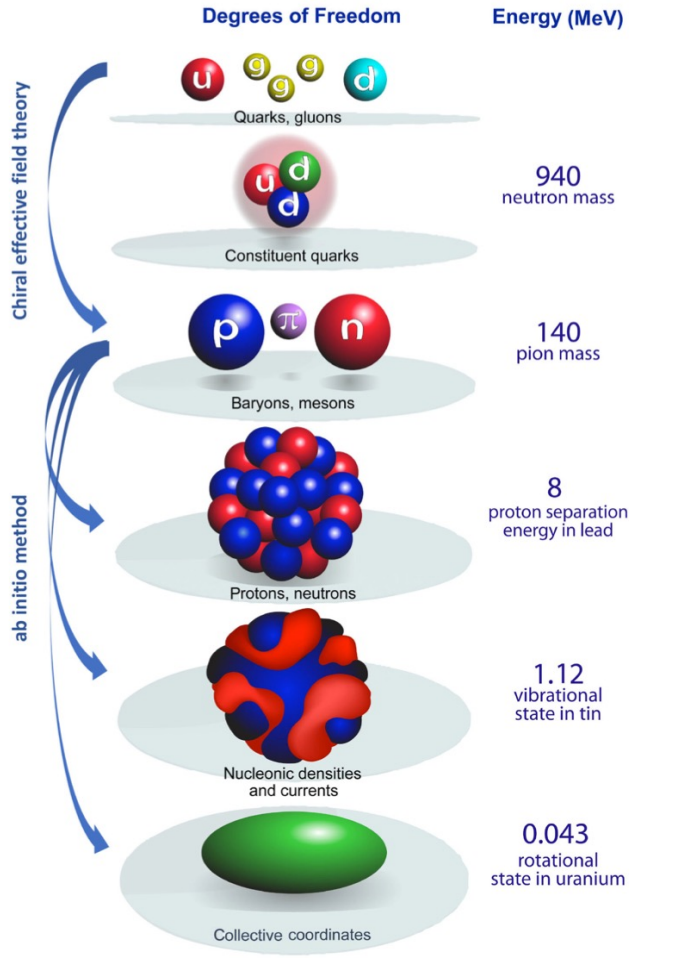


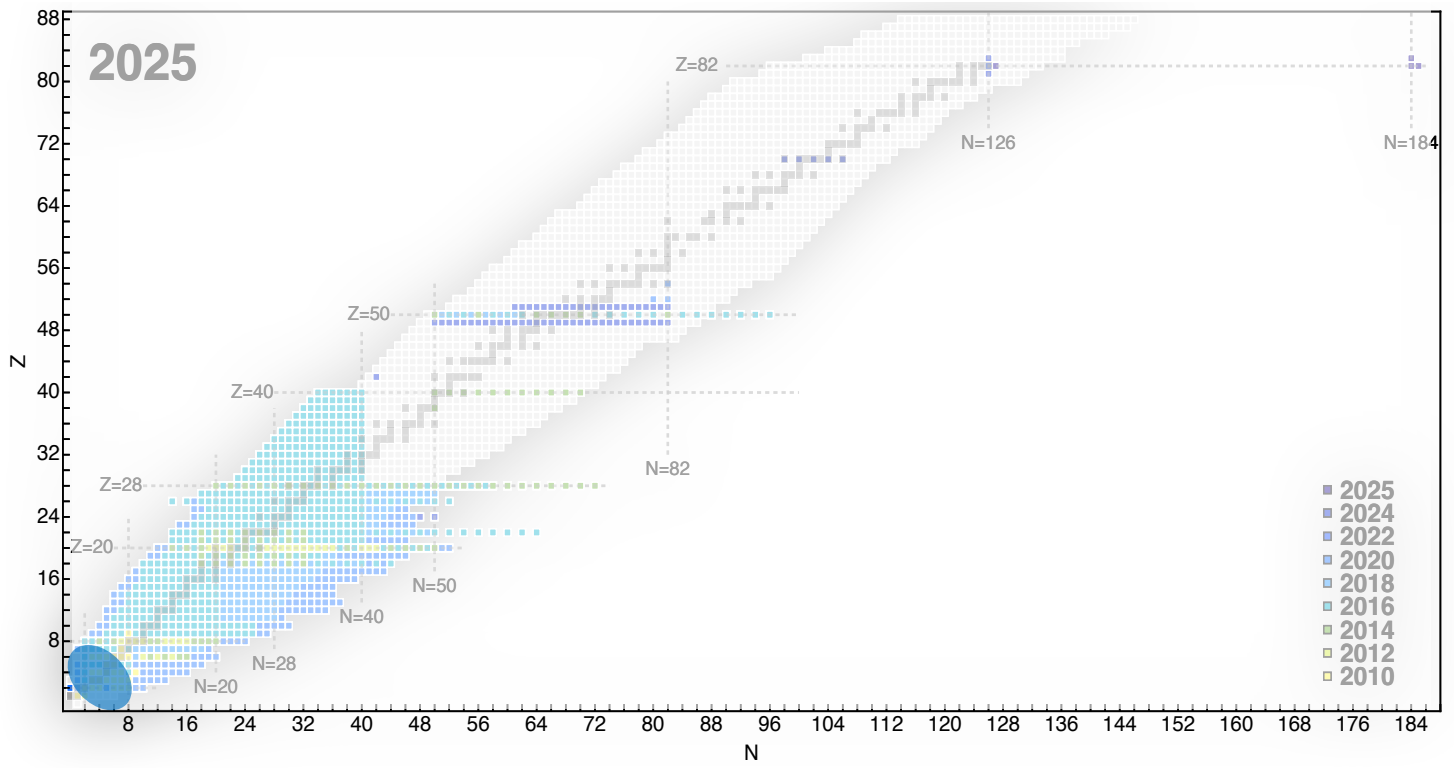
Z. Sun et al., PRX 15, 011028 (2025).



Credits: Heiko Hergert

Reactions from first principles are however mostly limited to light nuclei





Credits: Heiko Hergert

Z. Sun et al., PRX 15, 011028 (2025).

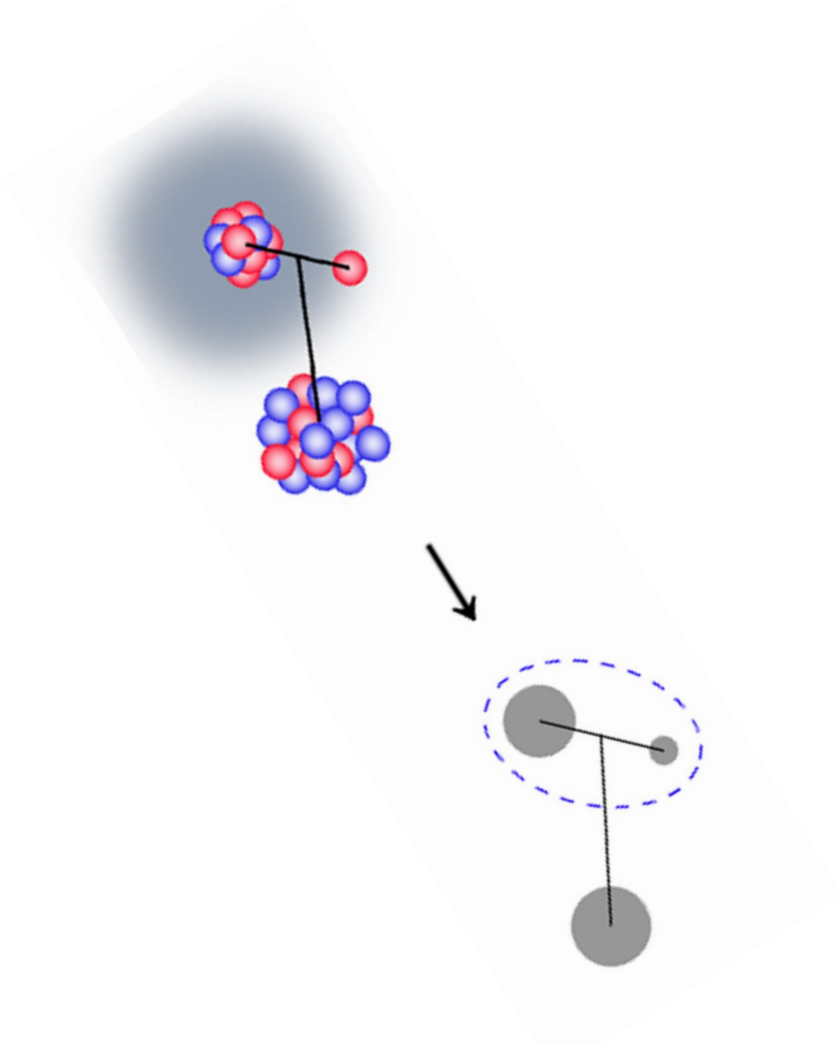
What do we need to move forward?

Synergies with few-body reaction theory

- The reaction problem can be simplified in a few-body description where both projectile and target are composed of one or more clusters of nucleons.

- Interactions among such clusters are modeled via optical potentials, fitted to experimental data.

- Different strategies to construct them: phenomenological, microscopic, derived from ab initio structure methods…

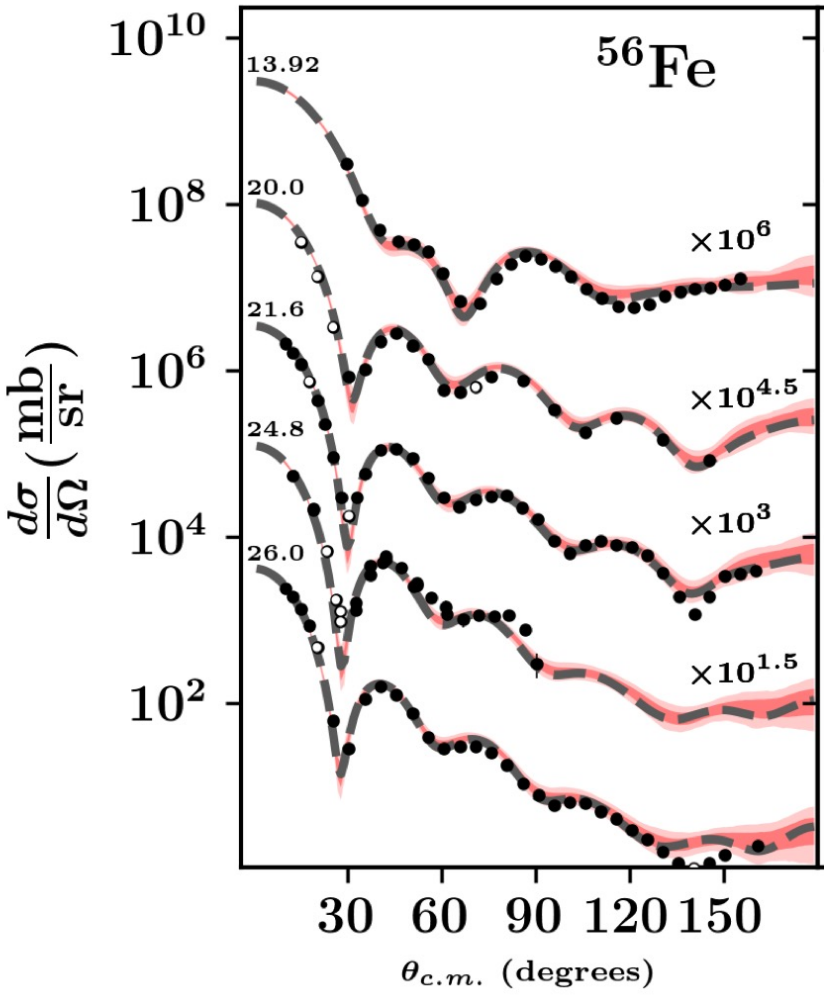


D. Bazin et al, Few-Body Syst 64, 25 (2023).

Synergies with few-body reaction theory

- Significant recent efforts in quantifying parametrization uncertainty.
- Still systematic uncertainties remain, and lack of experimental data in neutron-rich region makes it challenging to extrapolate.

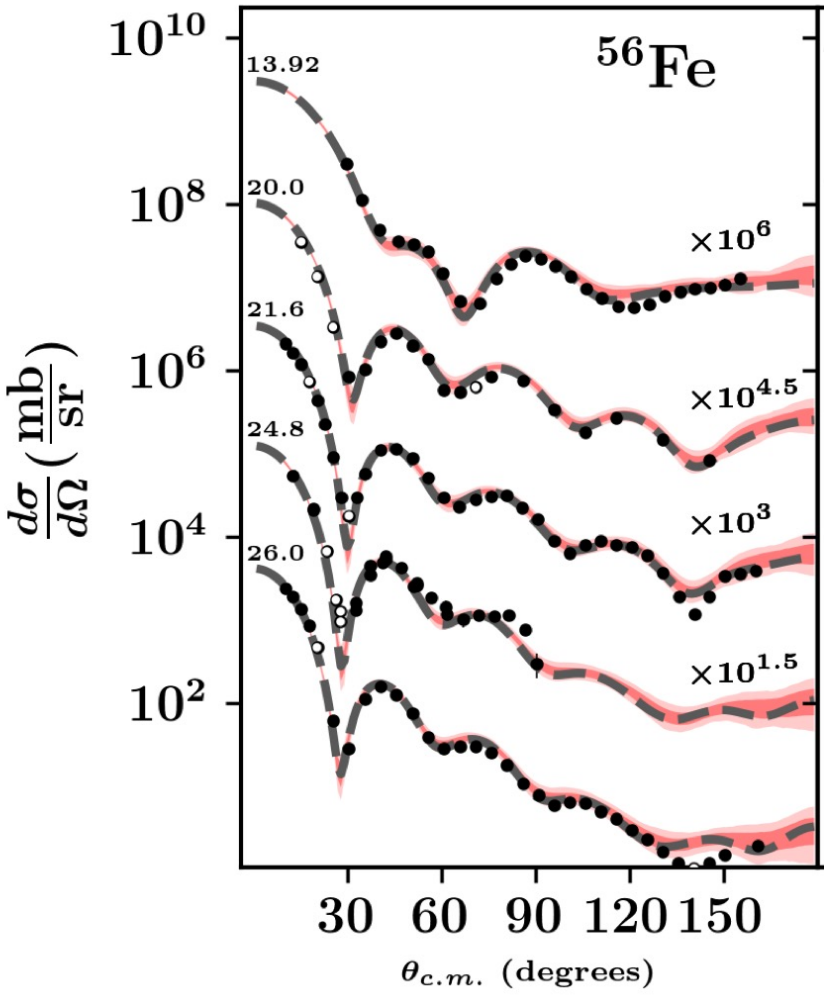
C.D. Pruitt et al, PRC 107, 014602 (2023)



Synergies with few-body reaction theory

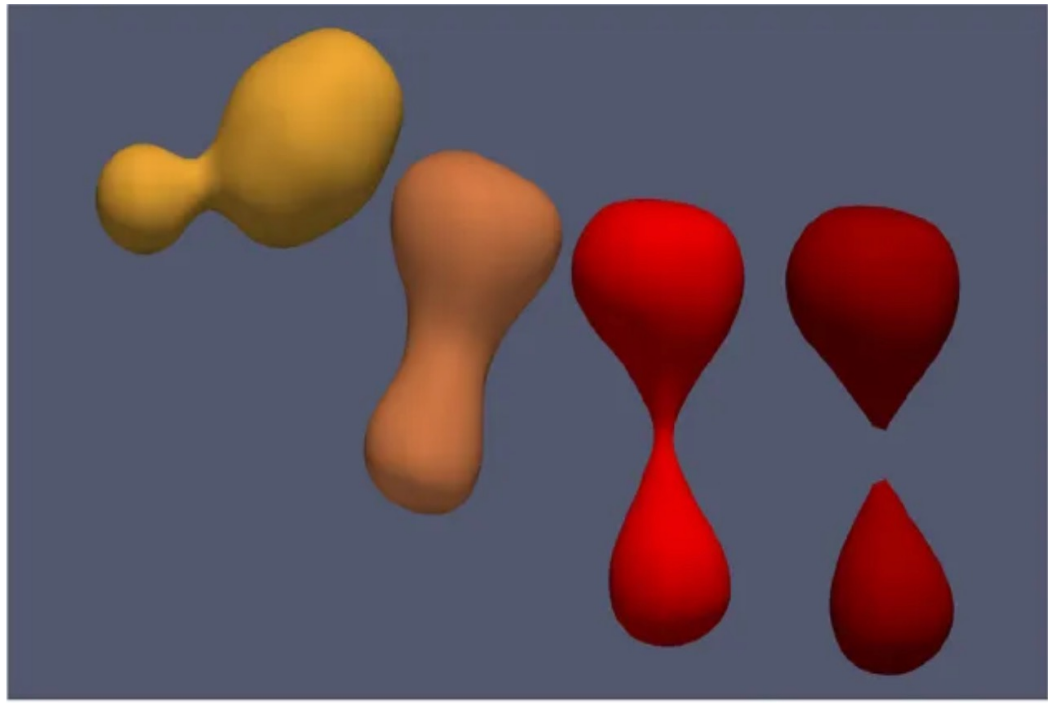
- How to constrain optical potentials taking advantage of nuclear structure progress?
- What are key aspects nuclear many-body theorists should work on to reach fully microscopic descriptions of reactions?

C.D. Pruitt et al, PRC 107, 014602 (2023)



Computational advances

- Reactions in heavy nuclei only accessible via time-dependent mean-field approaches (and some beyond-mean-field extensions).
- Most of these calculations are performed in coordinate space.
- Most polynomially scaling many-body methods are implemented in configuration space.

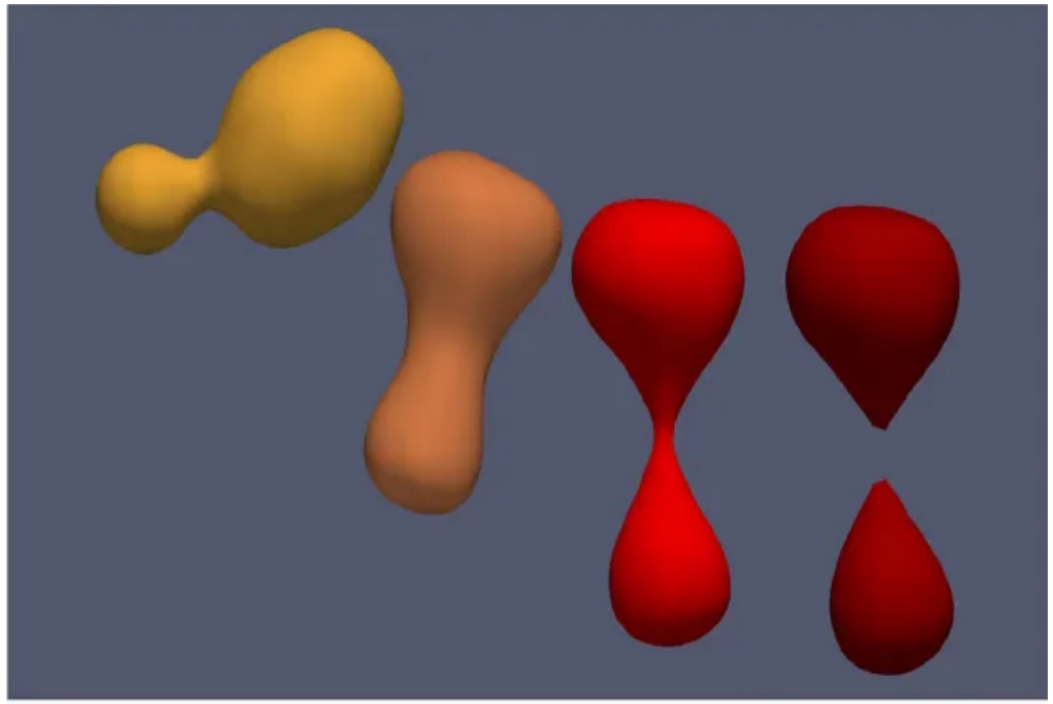


K. Godbey, A.S. Umar, Front. Phys. 8 (2020).

Computational advances

- How to bridge lattice-based time-dependent approaches to nuclear dynamics with polynomially scaling methods?

- Can quantum computing help on the way?

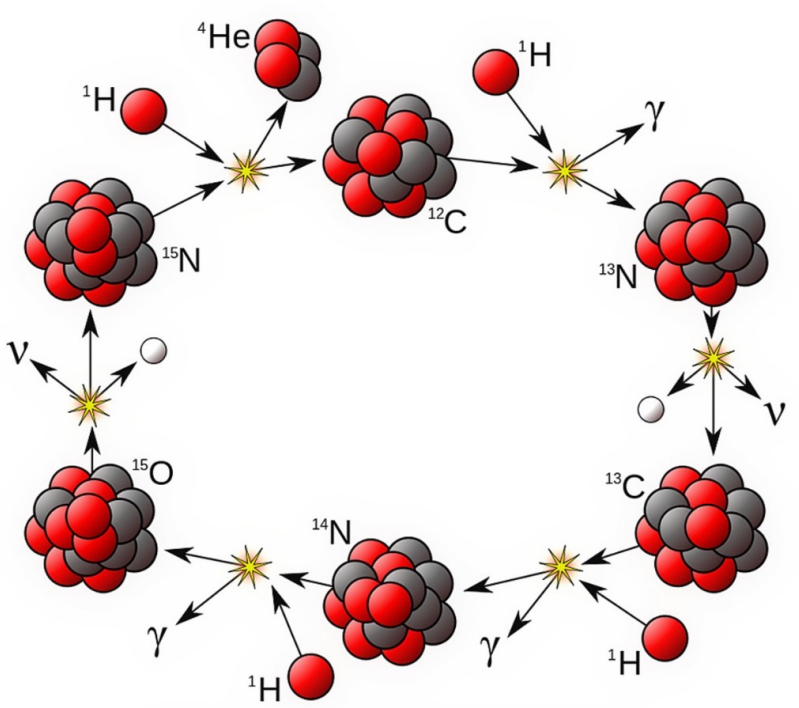


K. Godbey, A.S. Umar, Front. Phys. 8 (2020).

Milestones

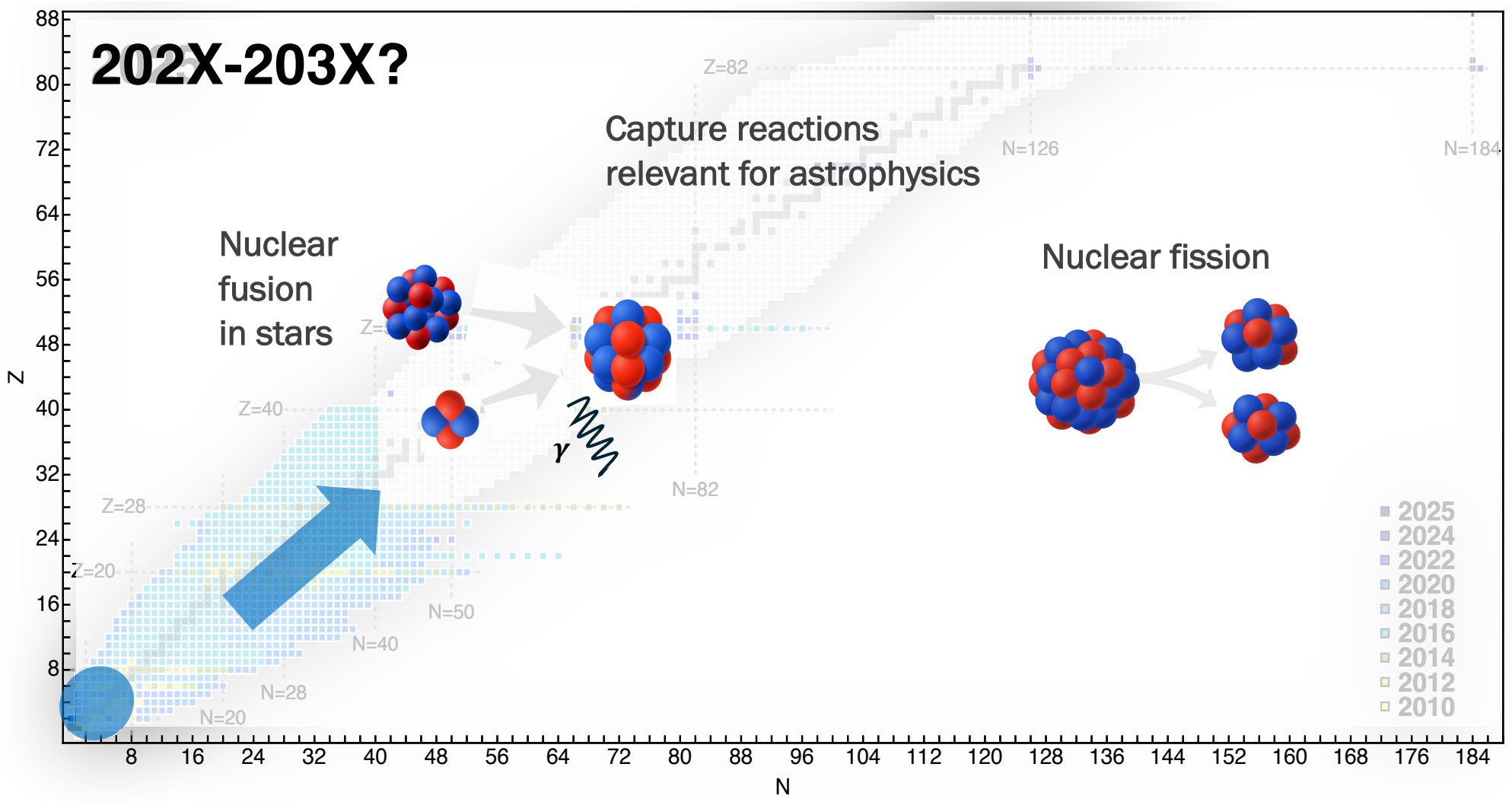
- What are key reactions for nuclear astrophysics that are ideal candidates for a completely microscopic description and can serve as benchmark for future many-body developments?

- Can the use of reaction data in optimizing/calibrating nuclear forces be useful? If yes, which observables are well suited for this purpose?



Credits: supernova.eso.org

Where we want to be



ECT* CODE OF CONDUCT

https://www.ectstar.eu/ect-code-of-conduct/

ECT* is committed to making its activities productive and enjoyable for everyone. All participants share the responsibility of fostering a supportive professional environment where open and frank discussion of ideas can take place, and where everyone is treated with courtesy and respect, regardless of their personal characteristics and background. We will not tolerate harassment of participants or others involved in ECT* in any form. For the entire duration of an ECT* activity and in other professional interactions with colleagues you agree to follow these guidelines:

Behave professionally in personal interactions as well as in any other form of communication including social media. Harassment and sexist, racist, or exclusionary comments or jokes are not appropriate. Harassment includes sustained disruption of talks or other events, inappropriate physical contact, sexual attention or innuendo, deliberate intimidation, stalking, and photography or recording of an individual without consent. It also includes, but is not limited to, offensive comments related to gender identity, sexual orientation, disability, physical appearance, body size, race, nationality, or the religion or non-religion of participants.

Be kind to others. Do not insult or put down attendees or other individuals associated with ECT*. Scientific discussion and criticism are vital and should be conducted in this spirit.

All communication should be appropriate for a professional audience including people of many different backgrounds. If participants wish to share photos of a speaker on social media, we strongly recommend that they first obtain the speaker's permission. Participants may share the contents of talks/slides via social media unless speakers have asked that specific details/slides should not be shared.

Should a participant be asked to stop any inappropriate behavior, they are expected to comply immediately. In serious cases, they may be asked to leave the activity at the sole discretion of the organizers and the ECT* Director. They may also be banned from participation in future activities.

Should a participant witness events of bullying, harassment or aggression, we recommend that they approach the affected person and show support. The witness may also suggest that the inappropriate behavior be reported and offer to facilitate that reporting if requested.

Participants can report any violation of these guidelines to the activity organizers, ECT* staff or the ECT* Director. Such reports will be treated confidentially.

Format

- ❑ Around 30 min talk + 30 min questions.
- ❑ 1 discussion session at the end of each day.
- ❑ Please highlight problems/open questions/challenges in your slides to stimulate discussion!

Challenges that we will address while also enjoying a beautiful city!



Benvenuti a Trento!