

# The role of universality and unitarity in nuclear physics

## Takeaways / Asks

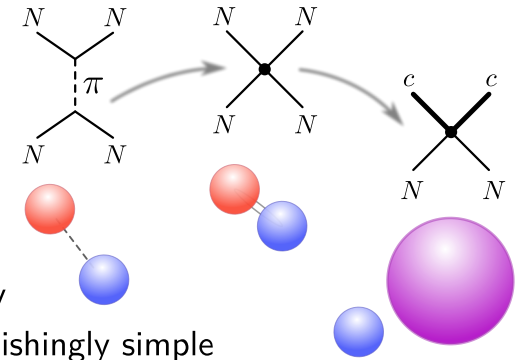
- please support theory
- unitarity and universality play a multi-faceted role in nuclear physics
- fundamental and practical questions are equally important

## Tenet 1: Emergent Complexity

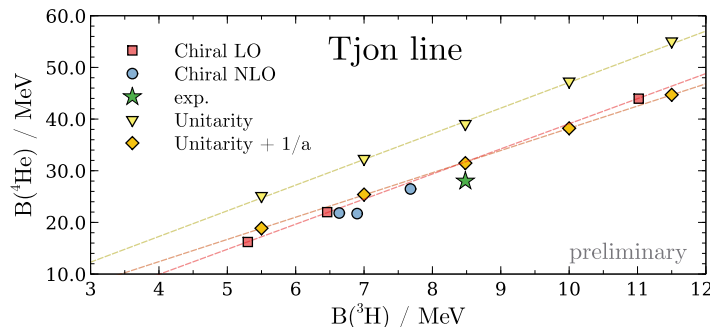
- the full richness of nuclear phenomena emerges out of Standard Model of Particle Physics (QCD + ...)
- QCD is **simple** (few parameters!) **in principle**, but **tremendously complex** (nonperturbative!) **in practice**
- Effective Field Theories (EFTs) provide a systematic bridge from QCD to nuclei regime, but many **questions remain regarding their construction and implementation**

## Tenet 2: Emergent Simplicity

- **large scattering length** (unitarity limit:  $a \rightarrow \infty$ ) governs physics irrespective of microscopic details  $\rightsquigarrow$  **universality**
- **recurring pattern in nuclear physics!**  $\rightarrow$  NN, halo nuclei, clustering
- properties of light nuclei can be expanded **perturbatively** around unitarity
- further results suggest that an effective nuclear interaction may be astonishingly simple



SK et al. PRL **118** 202501 ('17); Kievsky et al. PRL **121** 072701 ('18); Lu et al. PLB **797** 134863 ('19); Fossez et al. PRC **98** 061302 ('18)



## Conjectures and questions

- how simple can we go?
- complexity as perturbative "fine structure"?
- role of pion exchange/range in nuclear force?
- role of unitarity/universality in Chiral EFT?
- importance of multi-nucleon forces?

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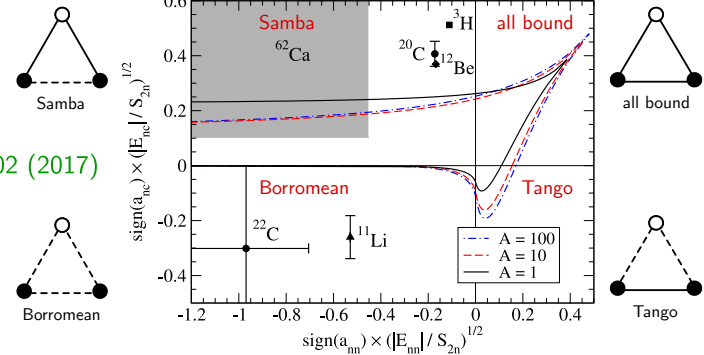
## Few-body cluster structures in exotic nuclei

- halo and cluster states often appear near the boundaries of nuclear stability
- physics driven by large inter-cluster scattering lengths
- **FRIB will produce a host of new data in this regime**
- concerted effort of theory and experiment is required to
  - ▶ **analyze experiments** involving effective few-body states
  - ▶ **constrain and refine theories** of the nuclear force



## Recent FRIB-TA Topical Program about this!

- produced a **collection of perspectives** [Bazin et al., arXiv:2211.06281](#)
  - ▶ emergence of few-body effects in many-nucleon systems
  - ▶ consistent theory for nuclear structure and reactions
  - ▶ inclusion of experimental and theoretical uncertainties
  - ▶ new opportunities to discover nuclear Efimov states
  - ▶ ... [figure adapted from Hammer et al., JPG 44 103002 \(2017\)](#)
- collaboration between experimentalists and theorists
- **written as inspiration for the community**



## Takeaways / Asks

- unitarity and universality play a multi-faceted role in nuclear physics
- fundamental and practical questions are equally important
- **please support theory, in particular at universities**

Thank you!