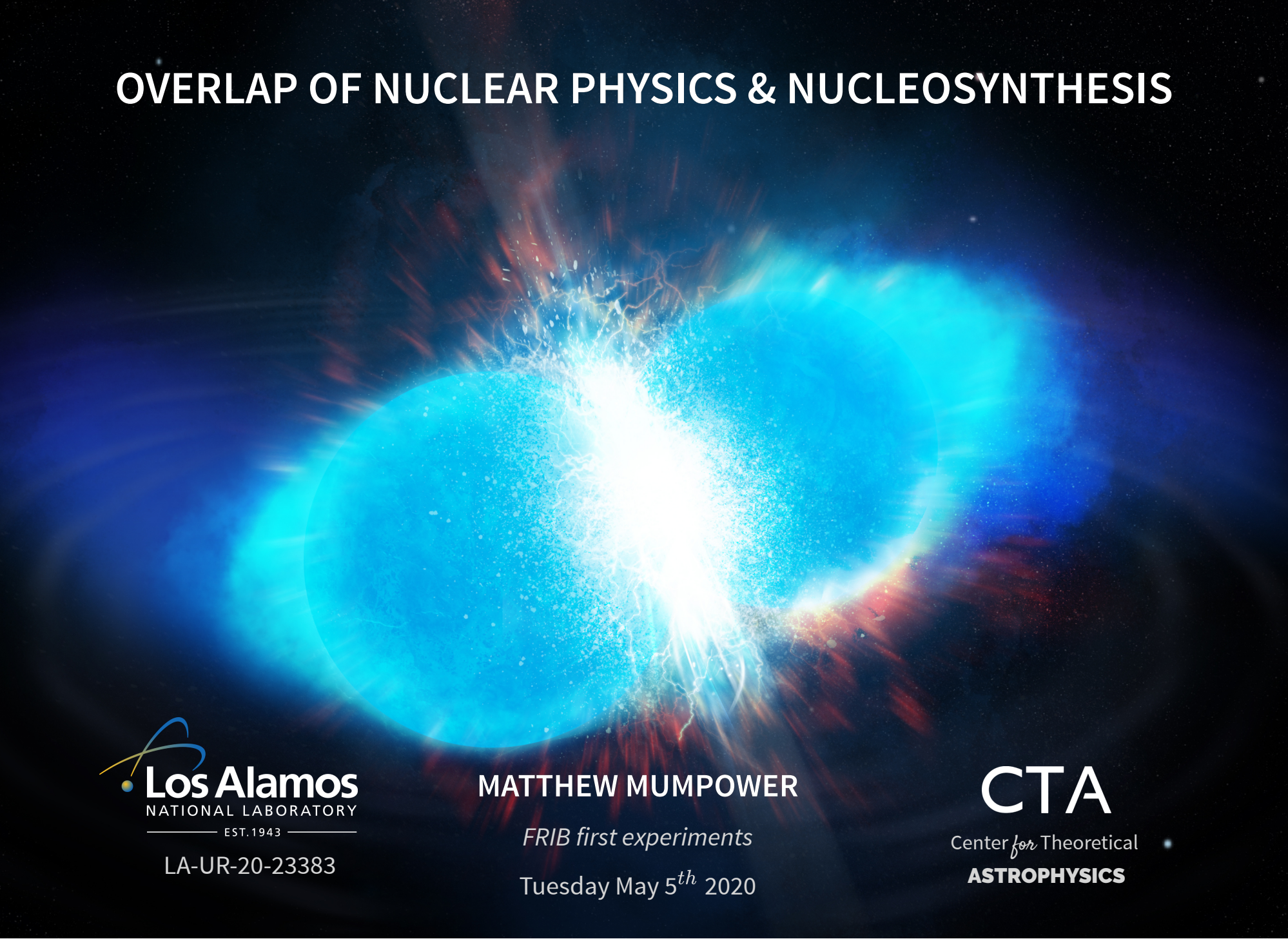
OVERLAP OF NUCLEAR PHYSICS & NUCLEOSYNTHESIS



Los Alamos NATIONAL LABORATORY EST. 1943

LA-UR-20-23383

MATTHEW MUMPOWER

FRIB first experiments

Tuesday May 5^{th} 2020

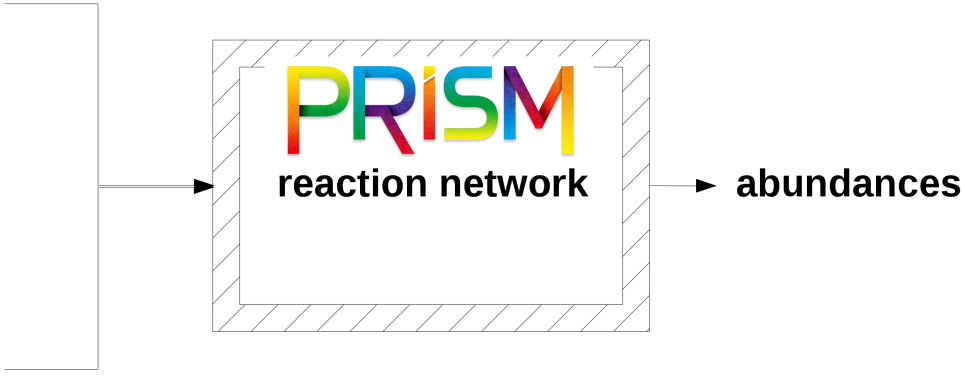
CTA Center for Theoretical ASTROPHYSICS

ABOUT MY WORK

I'm a theorist focused on the description of nuclear physics of neutron-rich nuclei

Trevor Sprouse and I have recently developed a novel platform for studying nucleosynthesis

nuclear physics inputs
(Sn, β-rates, n-cap rates, …)



thermodynamic conditions

(temperature, density, ...)

PRISM: Portable Routines for Integrated nucleoSynthesis Modeling

Code soon to be released as open source; 100's of GBs of nuclear data in the PRISM nuclear data interface (NDI)

Sprouse & **Mumpower** in prep. (2020)

NUCLEAR PHYSICS: THE LANGUAGE OF NUCLEOSYNTHESIS

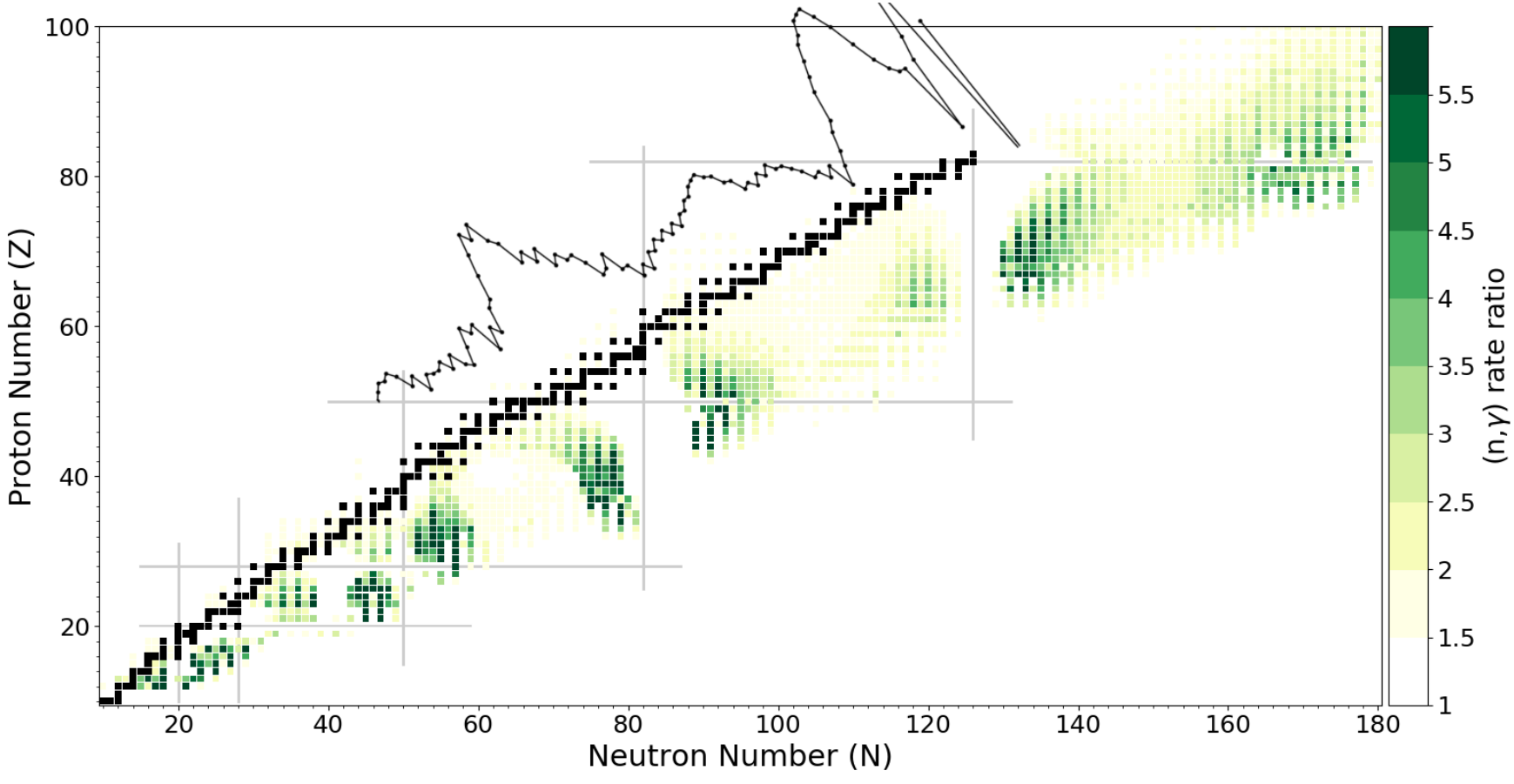
How the nuclei express themselves depends on the astrophysical conditions

This in turn, suggests what should be focused on for measurement campaigns

Ideally, we focus on measurements that will provide insight to both astrophysics & nuclear physics

See review paper: **Mumpower** *et al.* PPNP 86 (2016)

M1 ENHANCEMENT OF CAPTURE RATES



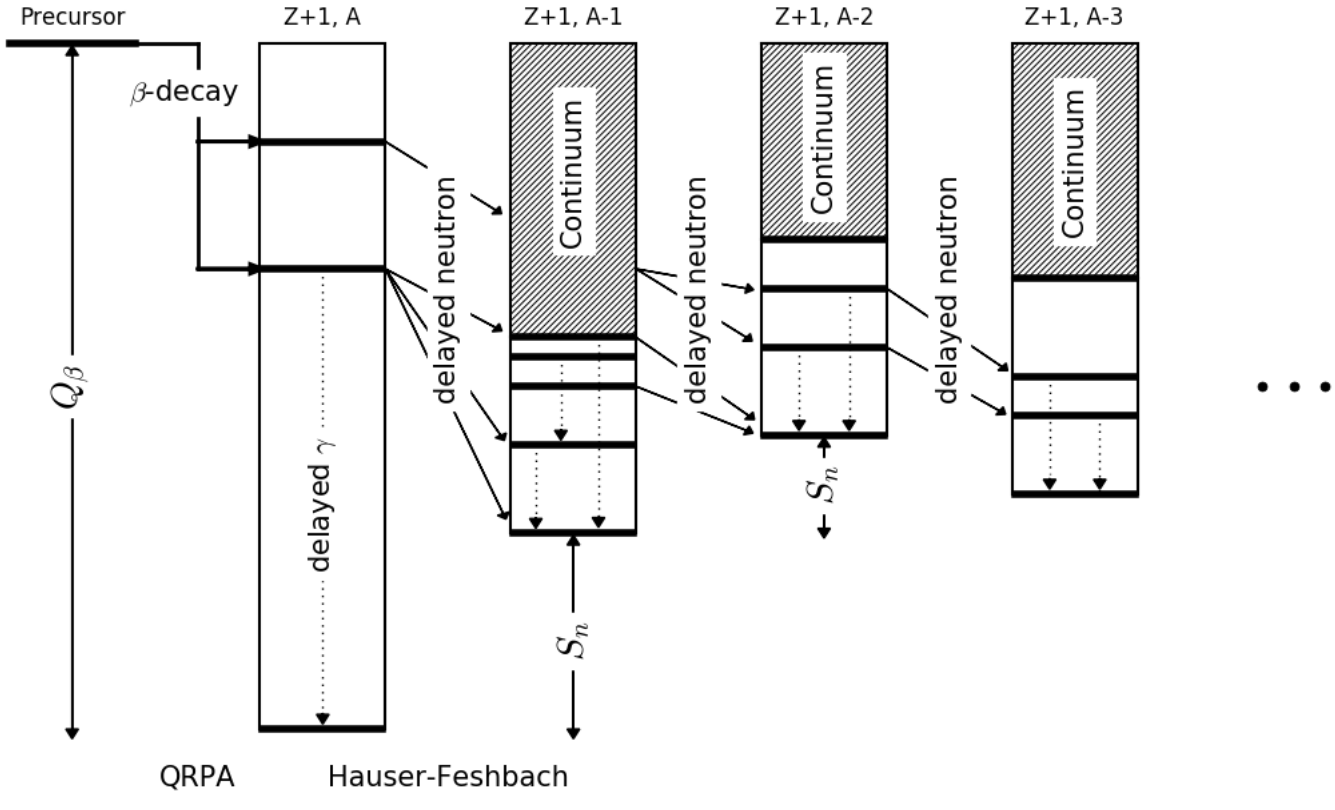
The impact (darker color) to neutron-rich nuclei is even larger than for those near stability

Many candidates (Ce, La, Pr) and lighter elements are well within the reach of FRIB reaction studies

An intriguing result... follows the solar isotopic pattern - *Juicy!*

Mumpower *et al.* PRC 96 024612 (2017)

NOVEL DESCRIPTION OF β-DECAY: QRPA + HF

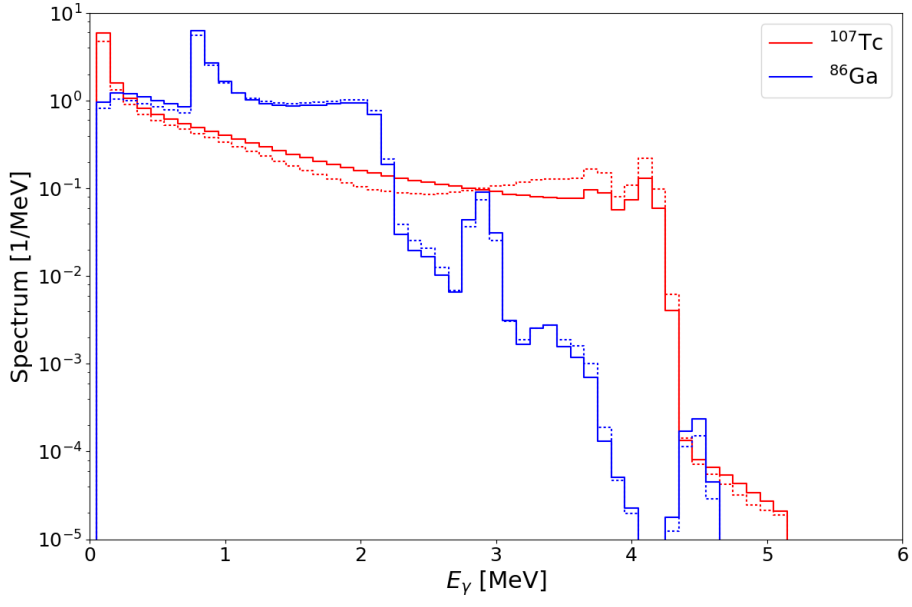


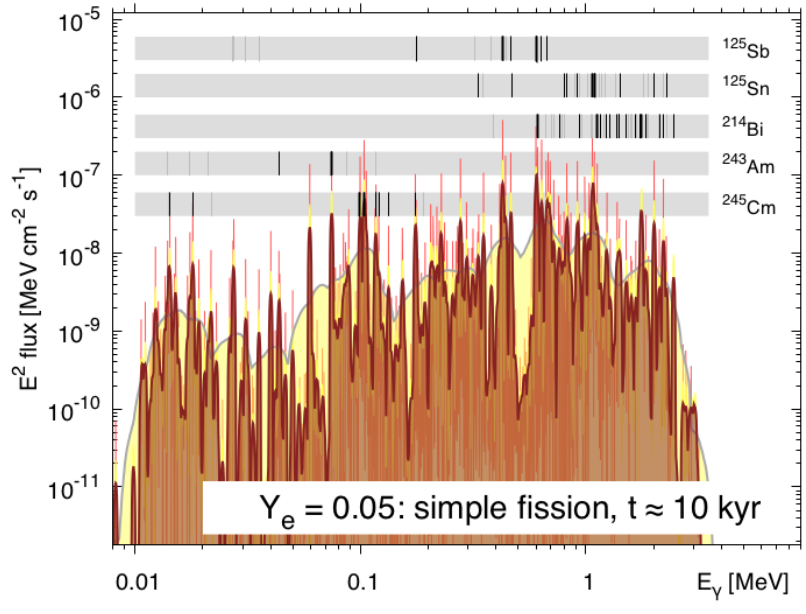
Initial population from the β-decay strength function from QRPA

Follow the statistical decay via Hauser-Feshbach until all excitation energy is exhausted

Mumpower *et al.* PRC 94 064317 (2016) • Spyrou ***et al.*** PRL 117 142701 (2016)
Wu *et al.* PRL 118, 072701 (2017) • **Mumpower** *et al.* ApJ 869 1 (2018) • Möller ***et al.*** ADNDT 125 (2019)

PARTICLE SPECTRA / OBSERVATIONS





Our QRPA+HF model is also capable of producing predictions of particle spectra (left)

Benchmarking these quantities provides a more sensitive test of the model beyond integral quantities such as P_n

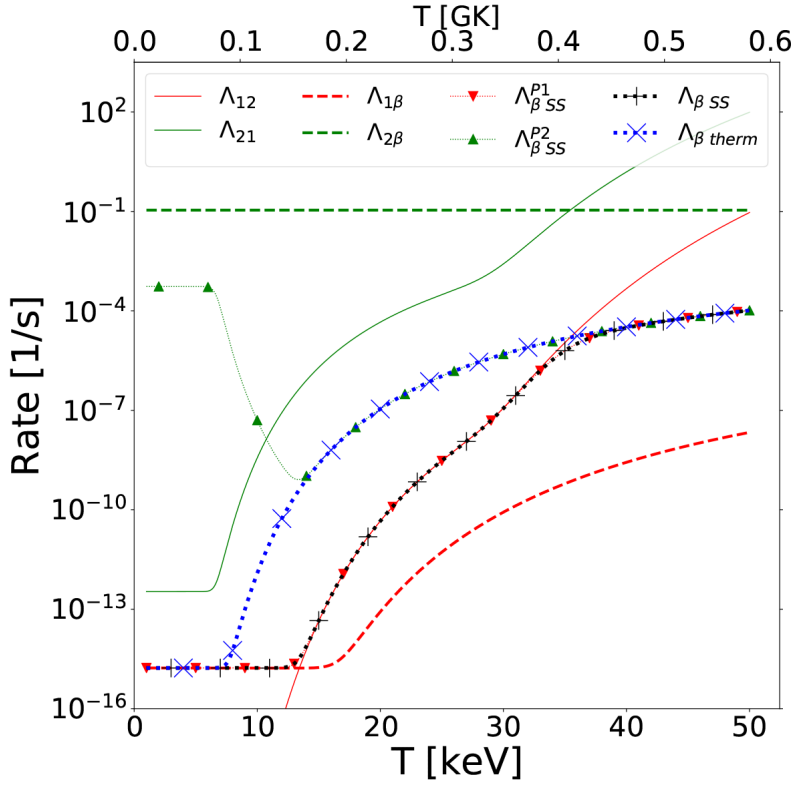
Both theory & data are influential in predicting observational signatures e.g. γ-rays from remnants (right)

Measurements focused on decays can provide a new handle on potential 'smoking gun' r-process nuclei

^{213,214}Bi($Z = 83$) are strong γ-emitters that have short half-lives but can be generated by longer-lived species

Korobkin ***et al.*** 889 2 (2020) • Miller ***et al.*** PRD 100 023008 (2019) • Wu ***et al.*** PRC 101 042801(R) (2020) • **Mumpower** *et al.* in prep. (2020)

ASTROPHYSICALLY RELEVANT NUCLEAR ISOMERS



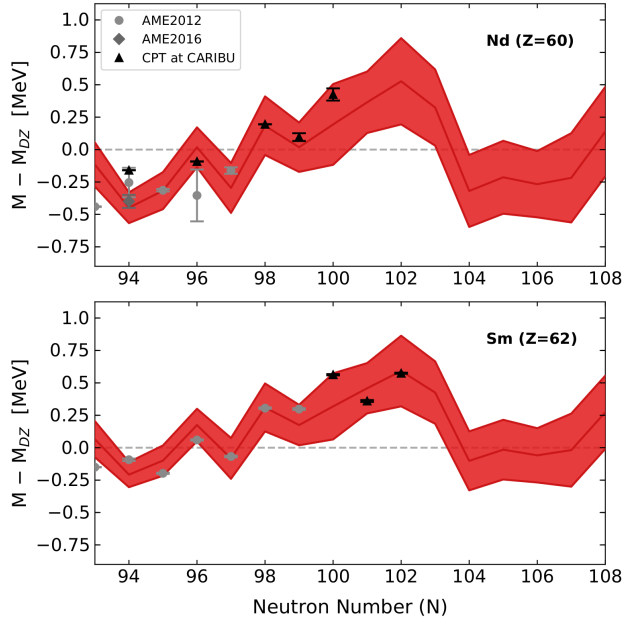
Wendell Misch (LANL postdoc) has been pioneering a new approach to nuclear isomers

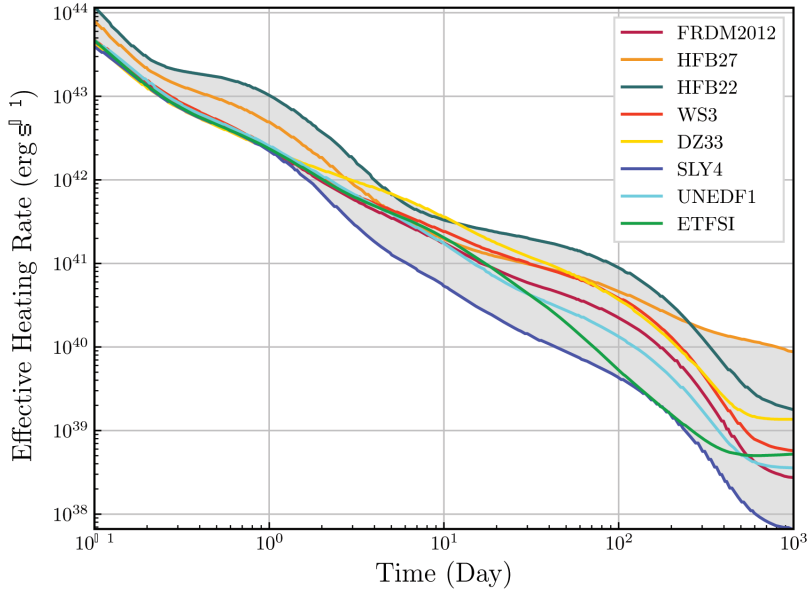
Famous example of an 'astromer': ^{26}Al

Our approach is broadly applicable to any environment, not limited to astrophysics

Misch ***et al.*** in prep. (2020) • Fujimoto & Hashimoto MNRAS 493 1 (2020)

MASS MEASUREMENTS





Bayesian model predictions for mass trends in rare earth nuclei (left) - Nicole Vassh

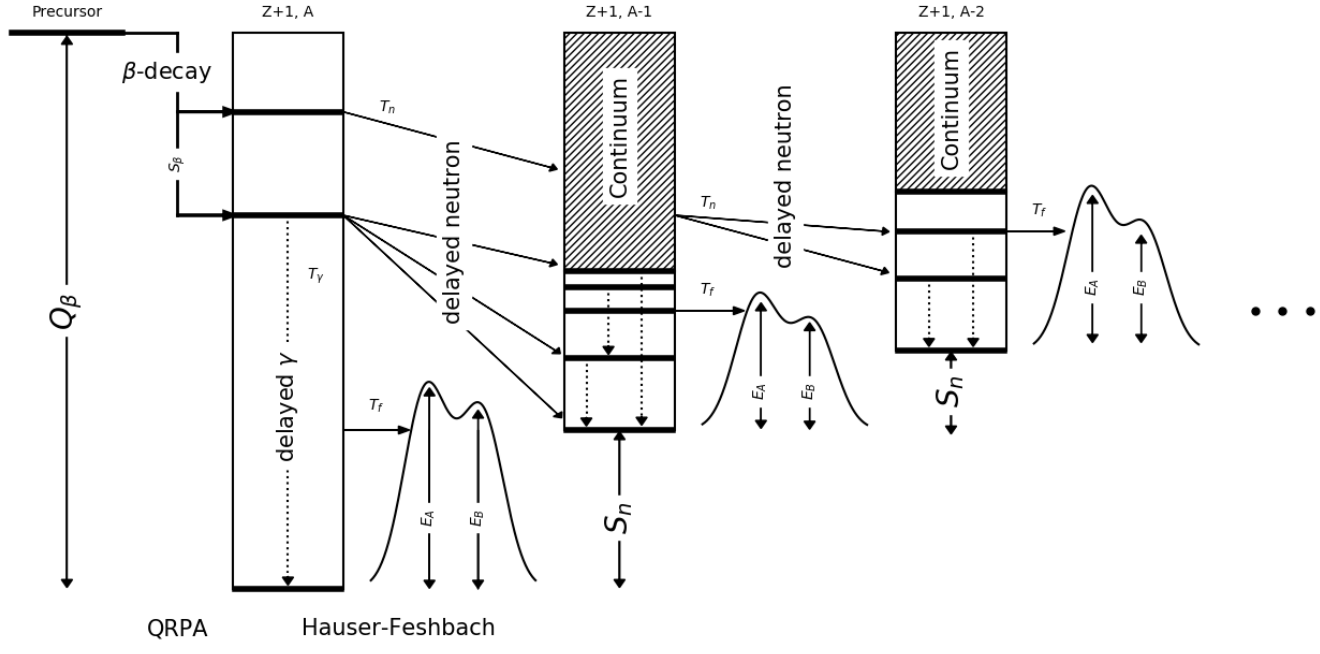
Targeted high-precision mass measurements can help to diagnose r-process conditions

Mass measurement campaigns can further help to address uncertainties in kilonova parameters (right)

Nuclei around $N = 126$ act as the gatekeepers for actinide production; strength of shell closure important!

Orford ***et al.*** PRL 120, 262702 (2018) • Vilen ***et al.*** PRL 120, 262701 (2018) Côté ***et al.*** ApJ 855 2 (2018) • Tang ***et al.*** PRL 124, 062502 (2020) • Zhu, Barnes ***et al.*** in prep. (2020) • Barnes ***et al.*** in prep. (2020) • Vassh ***et al.*** in prep (2020)

QRPA+HF APPLIED TO βDF



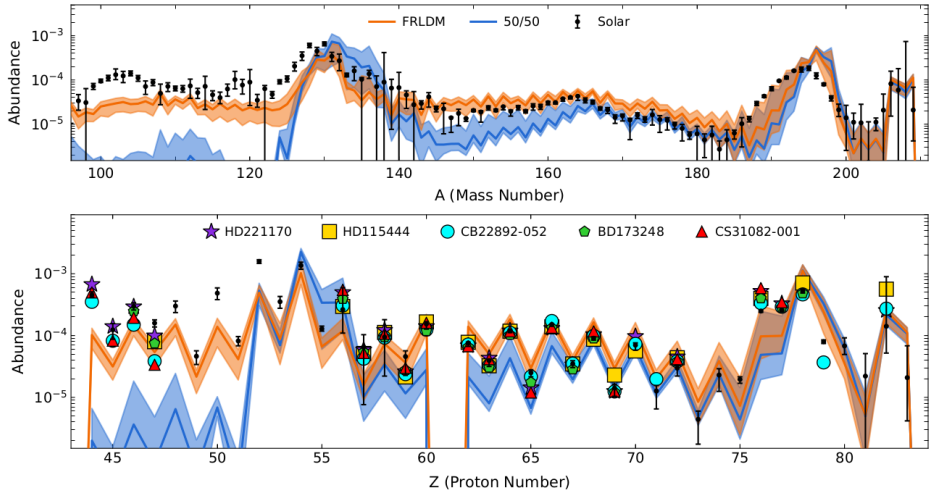
We have also explored multi-chance βdf - found to be an influential channel in the r-process

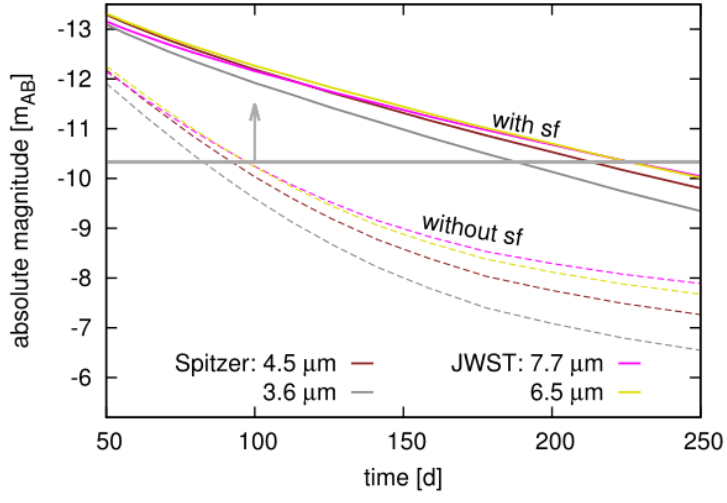
Future, exciting opportunities for studying this phenomenon in heavy elements...

Question: What can the high rigidity spectrometer (HRS) upgrade to FRIB do for fission studies?

Mumpower *et al.* ApJ 869 1 (2018)

FISSION & ACTINIDE STUDIES





We're in the process of releasing new fission fragment yield predictions to the community (impact left panel)

Fission is another area where we could find an observational 'smoking gun' of heavy element formation

New missions may be easily able to detect the presence of ^{254}Cf or other elements (right)

Measurements of yield and prompt emission are a vital test of model predictions

Fission may be one of the last pillars of uncertainty we must conquer to understand heavy element formation

Zhu ***et al.*** ApJL 863 2 (2018) • Vassh ***et al.*** J. Phys. G 46 065202 (2019) • Holmbeck ***et al.*** ApJ 881 1 (2019) • **Mumpower** *et al.* arXiv:1911.06344 accepted PRC (2020) • Vassh ***et al.*** arXiv:1911.07766 (2019)

SUMMARY

Nuclear physics is the *language* of nucleosynthesis

Recent advances:

We have developed a state-of-the-art research pipeline for studying nuclear physics in nucleosynthesis

We have novel theoretical tools to interpret experiments and gauge impact in astrophysical environments

We have recently compiled new mass, reaction, decay and fission predictions across the chart of nuclides

Measurements will have a tremendous impact on theoretical nuclear modeling, nucleosynthesis and observations

I'm looking forward to the exciting opportunities at FRIB!

Results / Data / Papers @ MatthewMumpower.com