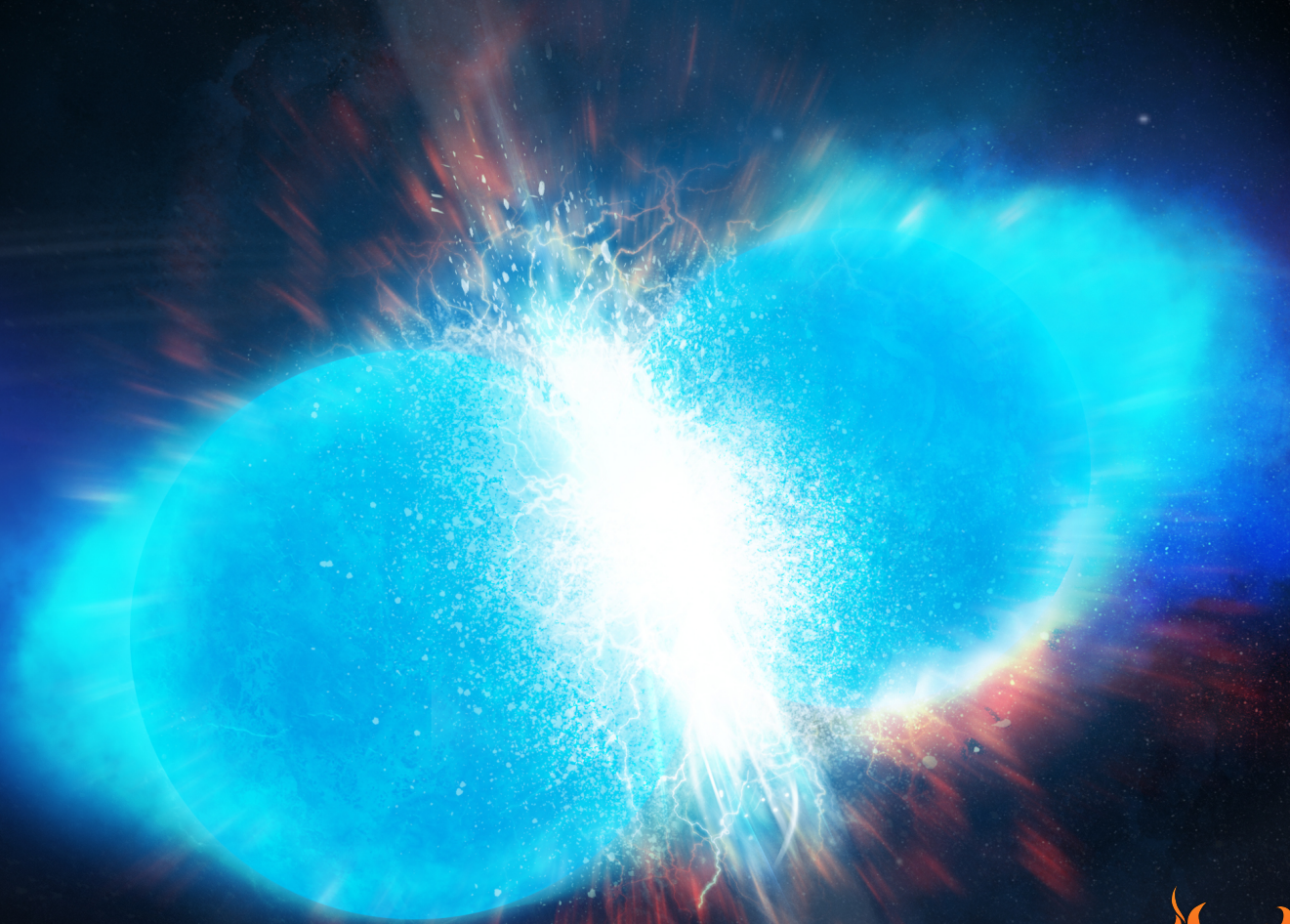


FISSION IN THE r -PROCESS



LA-UR-19-22694

MATTHEW MUMPOWER

Frontiers (2019)

Wednesday May 22nd 2019



FIRE Collaboration

Fission In R-process Elements

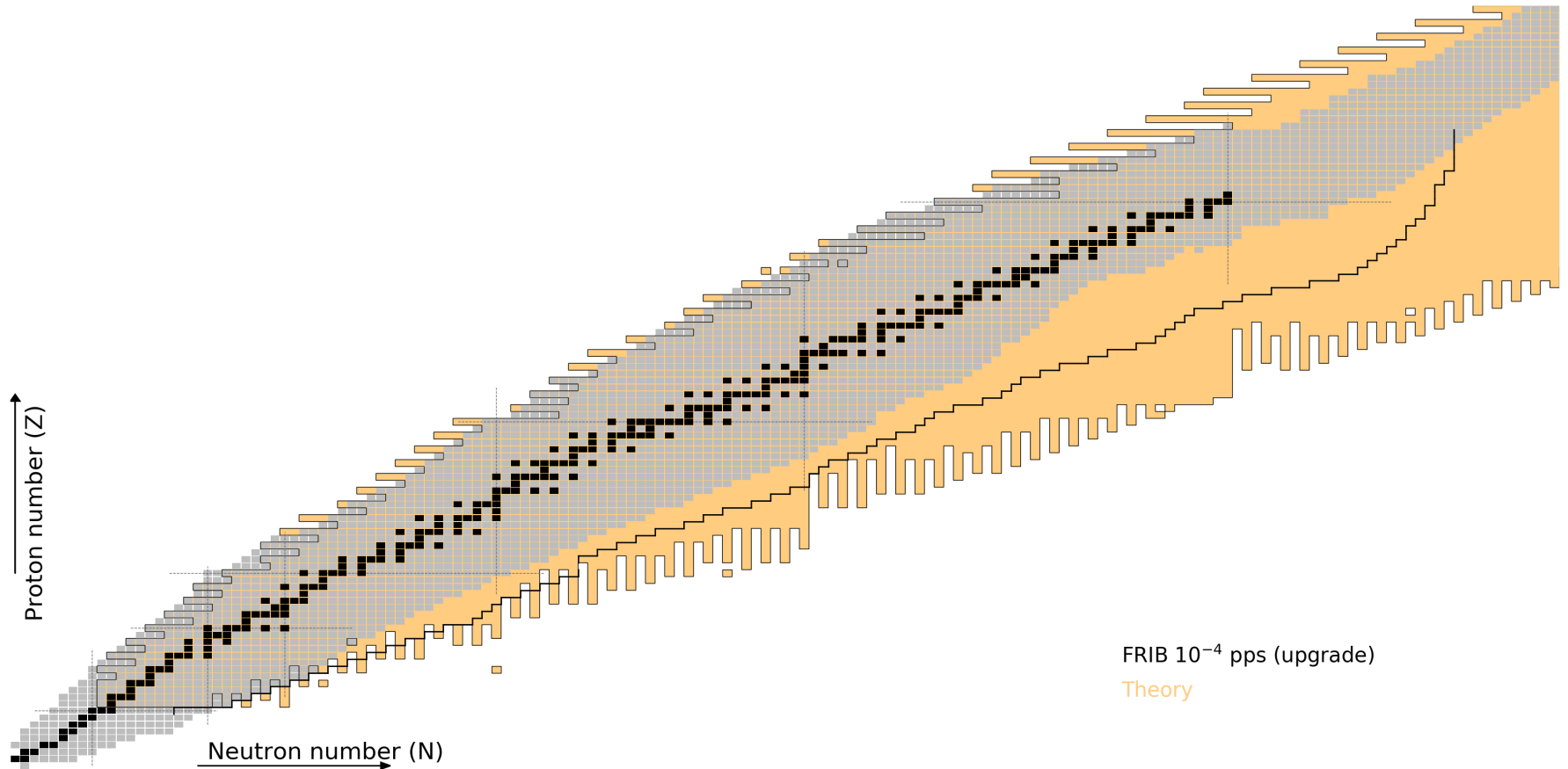
NUCLEAR PHYSICS AS THE LANGUAGE OF THE r -PROCESS

1st order: masses, β -decay rates, capture rates & fission



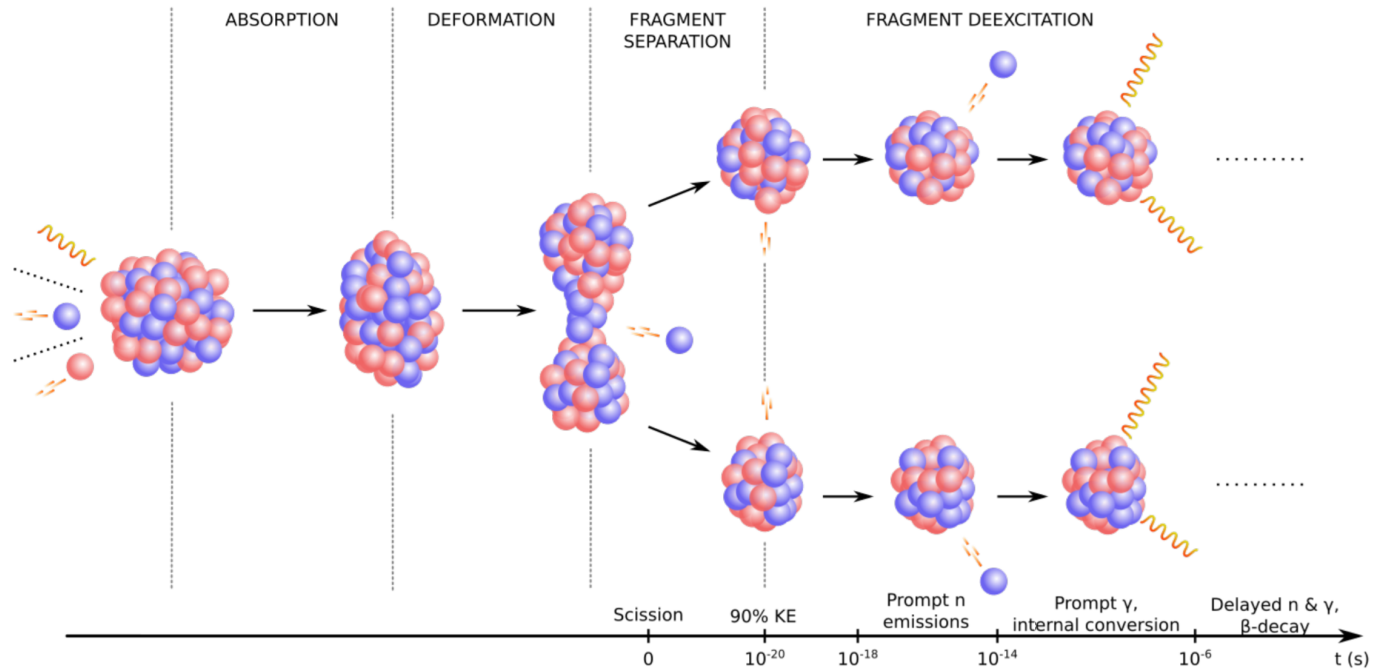
MUCH WILL BE MEASURED AT FRIB

But fission studies will remain relatively **inaccessible**



∴ Fission **theory** is **critical** find any sort of "**smoking gun**" of heavy element production

NUCLEAR FISSION IN A NUTSHELL



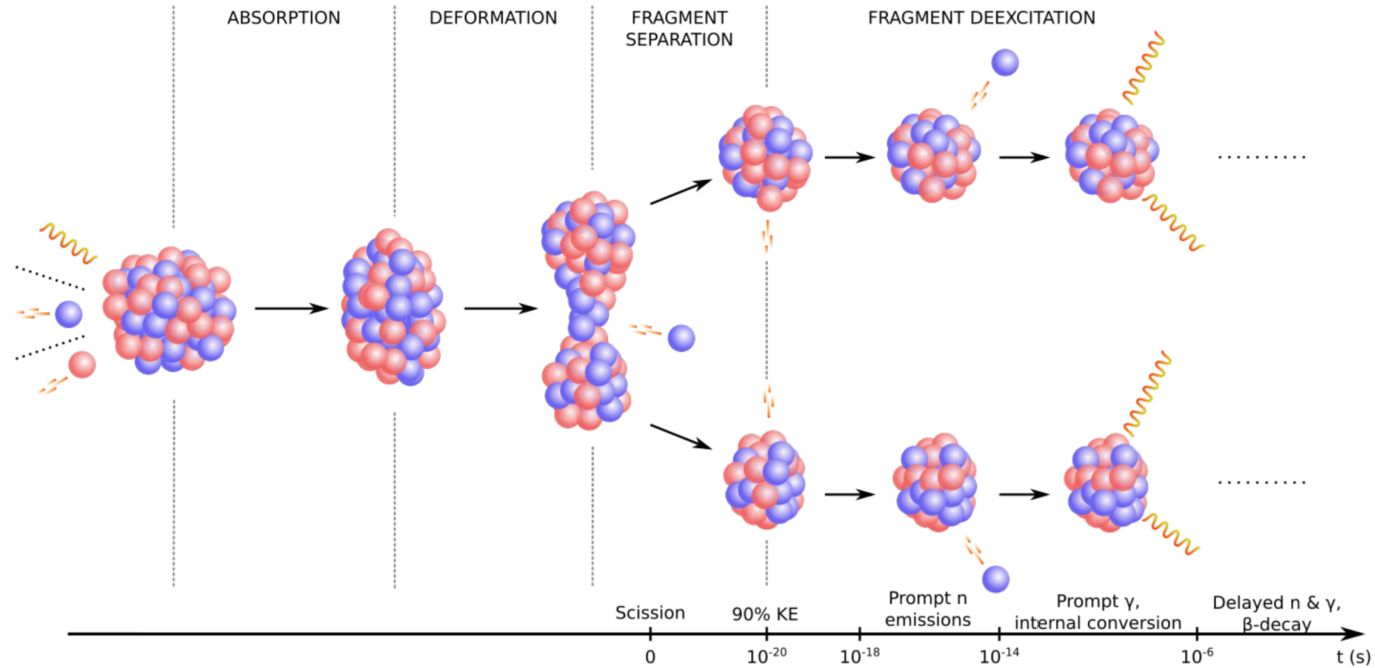
The fission process:

A heavy nucleus splits into two lighter fragments

Subsequent particle emission and decays then occur

Many events gives rise to fission yield

NUCLEAR FISSION FOR THE r -PROCESS



Influence on the r -process:

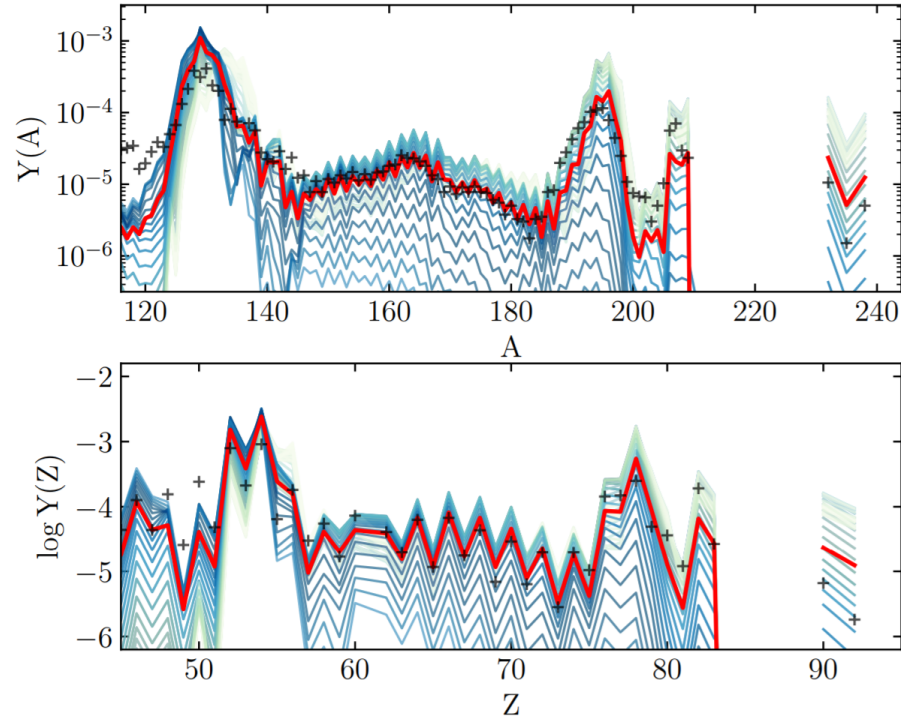
Fission **rates** and **branching** determine re-cycling (robustness)

Fragment **yields** place material at lower mass number; barriers determine hot spots

Large **Q-value** \Rightarrow impacts thermalization and therefore possibly **observations**

Responsible for what is left in the heavy mass region when nucleosynthesis is complete \Rightarrow "**smoking gun**"

LONG-LIVED ACTINIDES

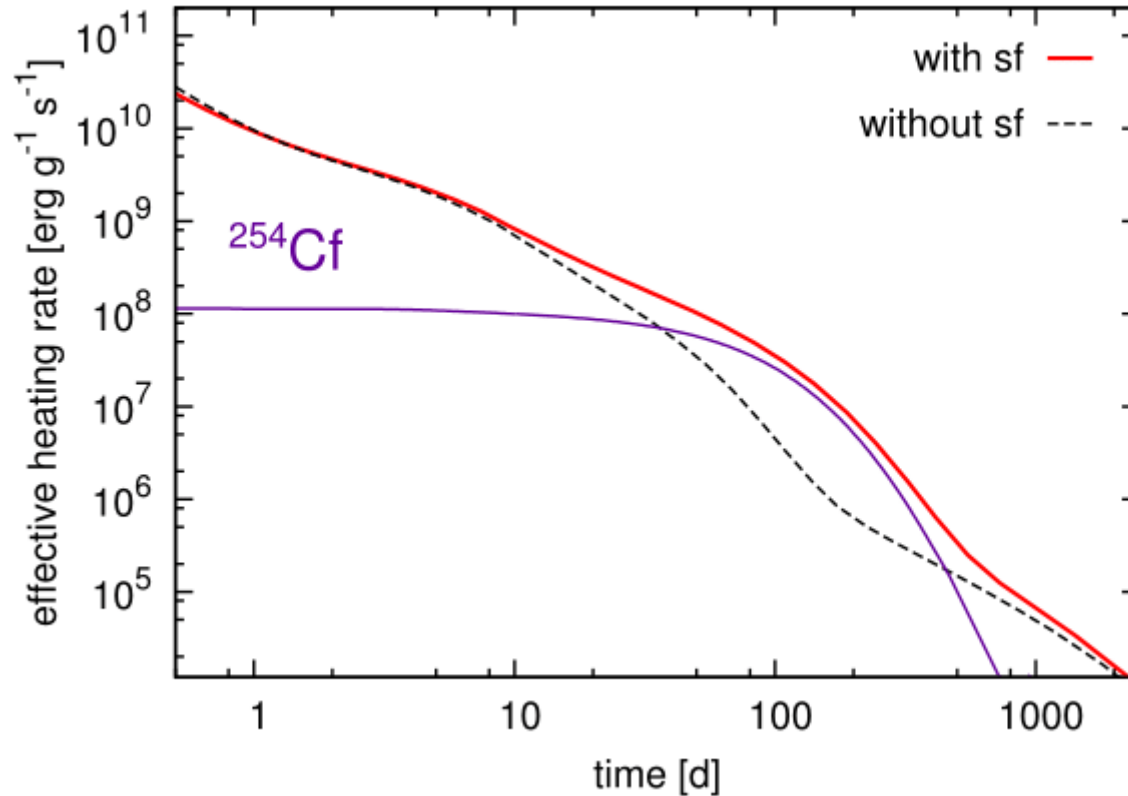


Recent calculations show: if **actinides** are produced, they are usually overproduced versus **lanthanides**

A sufficient amount of **dilution** with lighter r -process material is required to match the solar isotopic residuals

\therefore Fission theory can also inform us on **galactic chemical evolution**

ONE EXAMPLE: ^{254}Cf (Z=98)

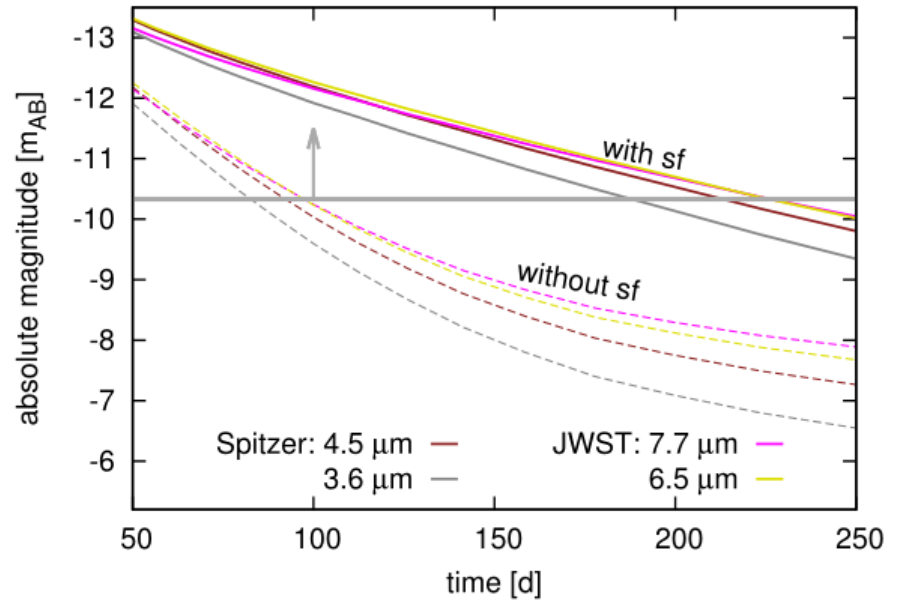
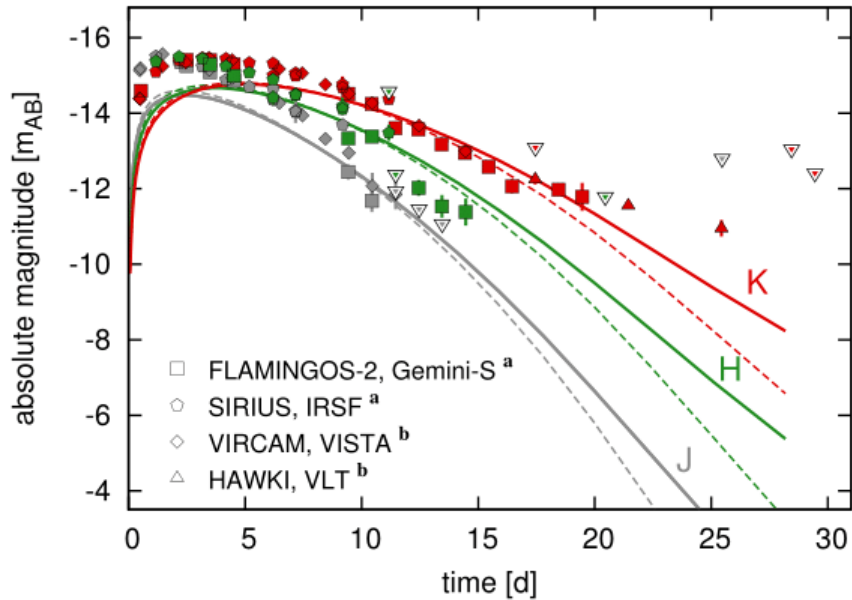


Is there any possible precursor to show that actinide nucleosynthesis has occurred in an event?... Maybe!

The spontaneous fission of ^{254}Cf can be a primary contributor to nuclear heating at late-time epochs

The $T_{1/2} \sim 60$ days; found from nuclear weapons testing

OBSERVATIONAL IMPACT OF CALIFORNIUM



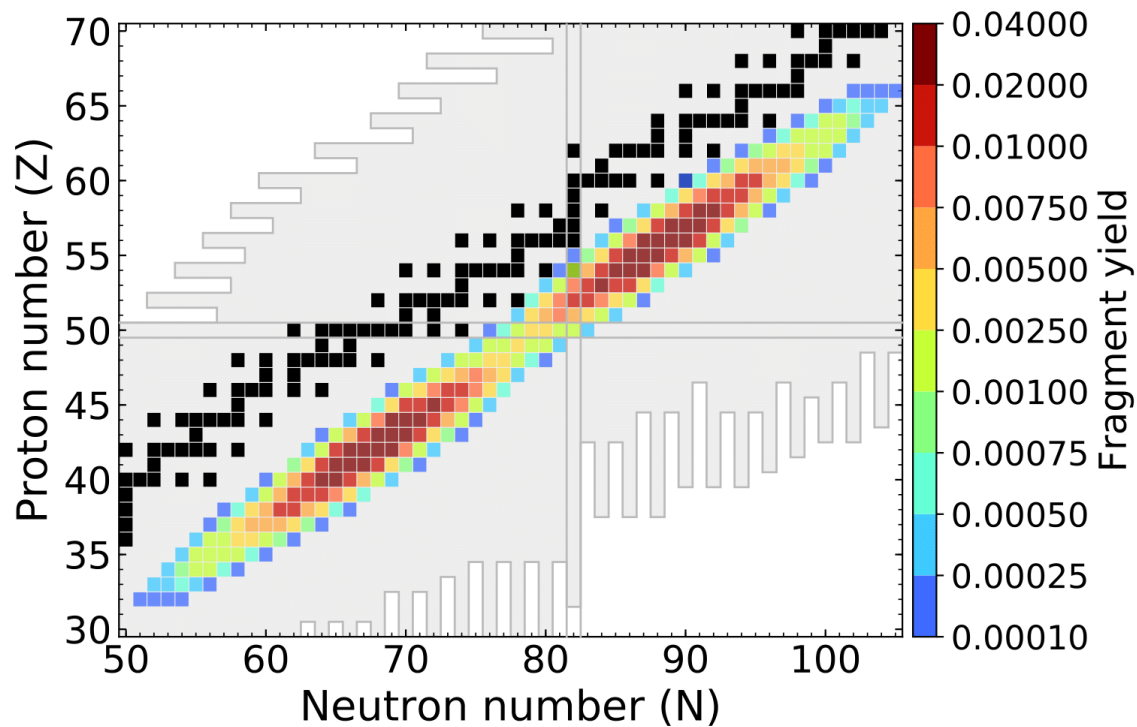
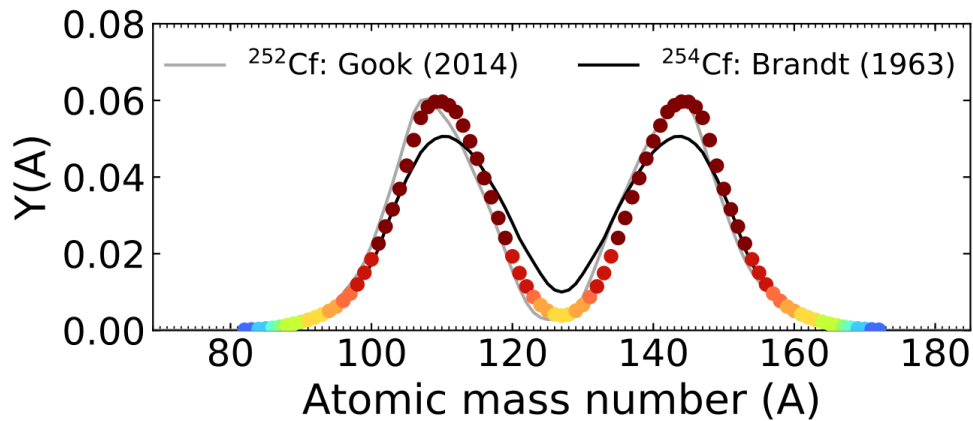
Both near- and middle- IR are impacted by the presence of ^{254}Cf

Late-time epoch **brightness** can be used as a **proxy** for **actinide** nucleosynthesis

Future JWST will be detectable out to 250 days with the presence of ^{254}Cf

This also has implications for merger morphology...

CALCULATED YIELD (CALIFORNIUM)



SPECIAL THANKS TO

My collaborators

A. Aprahamian, J. Barnes, B. Côté, J. Clark, C. Fryer, E. Holmbeck, A. Hungerford, P. Jaffke, T. Kawano, O. Korobkin, S. Liddick, G. C. McLaughlin, J. Miller, P. Möller, R. Orford, J. Randrup, G. Savard, A. Sierk, N. Schunck, T. Sprouse, A. Spyrou, I. Stetcu, R. Surman, P. Talou, N. Vassh, M. Verriere, R. Vogt, Y. Zhu
& many more...

■ Students ■ Postdocs ■ FIRE ■ LANL

SUMMARY

The r -process relies on fission in many ways:

Re-cycling material ▲ Actinide production ▲ Late-time observations

FRIB and other facilities will make a lot of measurements, but fission studies remain relatively **inaccessible**

Fission theory is **crucial** to understanding the formation of the heaviest elements (and $A \sim 130$)

The **FIRE** Collaboration will soon provide a suite of new fission properties for the community:

Rates • Branchings • Yields • Q-values • Spectra

Results / Data / Papers @ MatthewMumpower.com