Sensitivity of the Observed Kilonova Signal to Nuclear Physics

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with
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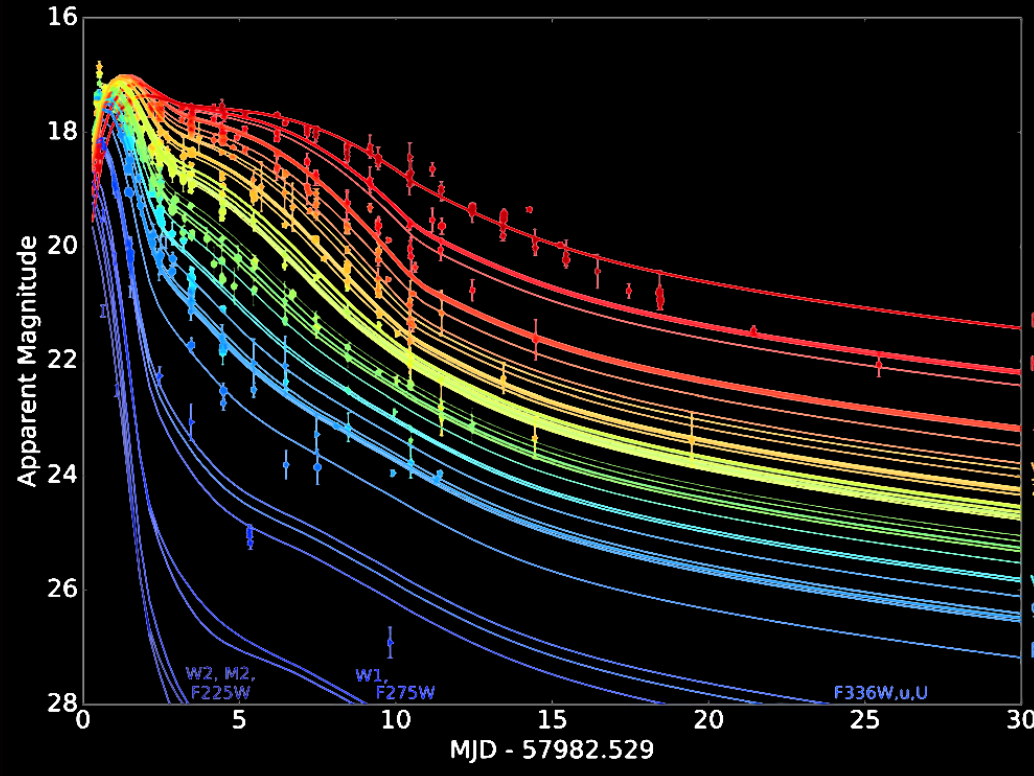
KN observation points to relevance of multi-component models as a tool for studying the extent of r-process production:

- "Blue" component → free of high-opacity lanthanides *(Evans+ 2017, Miller+ 2019)*

- "Red" component → high-opacity lanthanides and/or actinides produced via the r-process *(Evans+ 2017)*



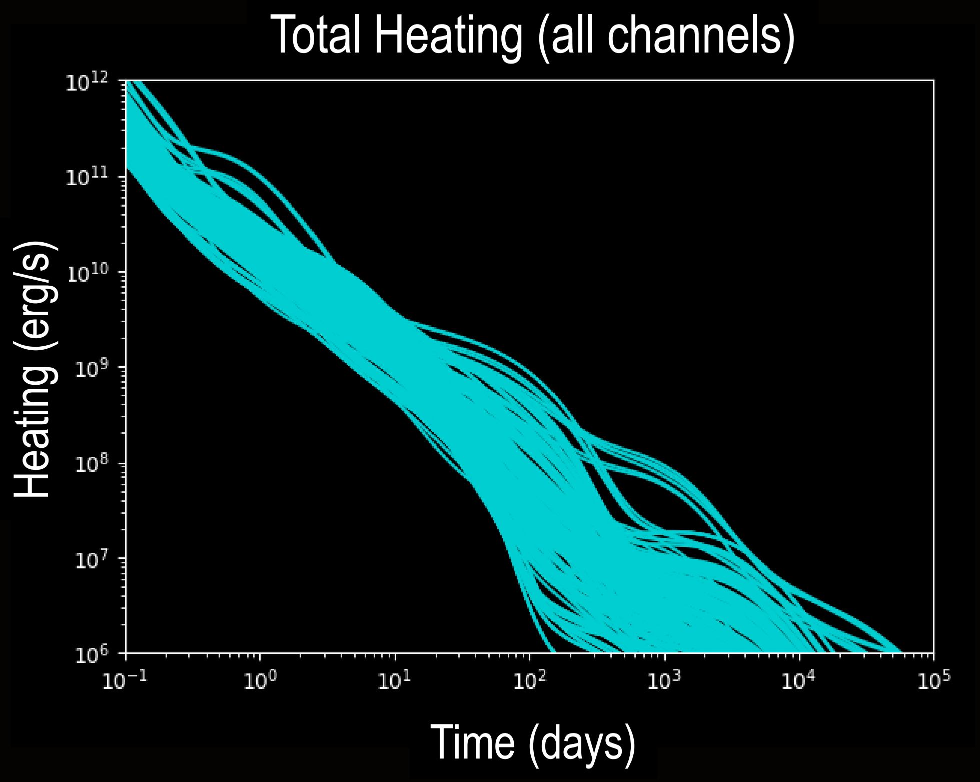
(Adapted from Villar+ 2017)

Nuclear heating as a “basic ingredient” for light curves:

The transient event is understood to be powered by radioactive decays; therefore, we want to model ***how much*** of and ***what*** gets made in order to track differences in KN heating and light curves.

During simulation: Evolution of material far from stability, lack of experimental information, sensitivity to astrophysical and nuclear physics inputs.

After simulation: Use data to calculate total and fractional heating from radioactive decays on timescales of days.



- Mass Model* & Fission Barrier Height (x8)

SLY4 Chabanat+ (1998), Möller+ (2015)	(FRLDM)
UNEDF1 Kortelainen+ (2012), Möller+ (2015)	(FRLDM)
DZ33 Duflo & Zuker (1995), Möller+ (2015)	(FRLDM)
ETFSI Aboussir+ (1995), Mamdouh+ (1998)	(ETFSI)
FRDM2012 Möller+ (2015,2016)	(FRLDM)
HFB22,27 Goriely+ (2009,2013)	(HFB)
WS3V6 Liu+ (2011), Möller+ (2015)	(FRLDM)

- Spont. Fission Rate (x2) (Karpov+ 2012; Xu&Ren 2005)

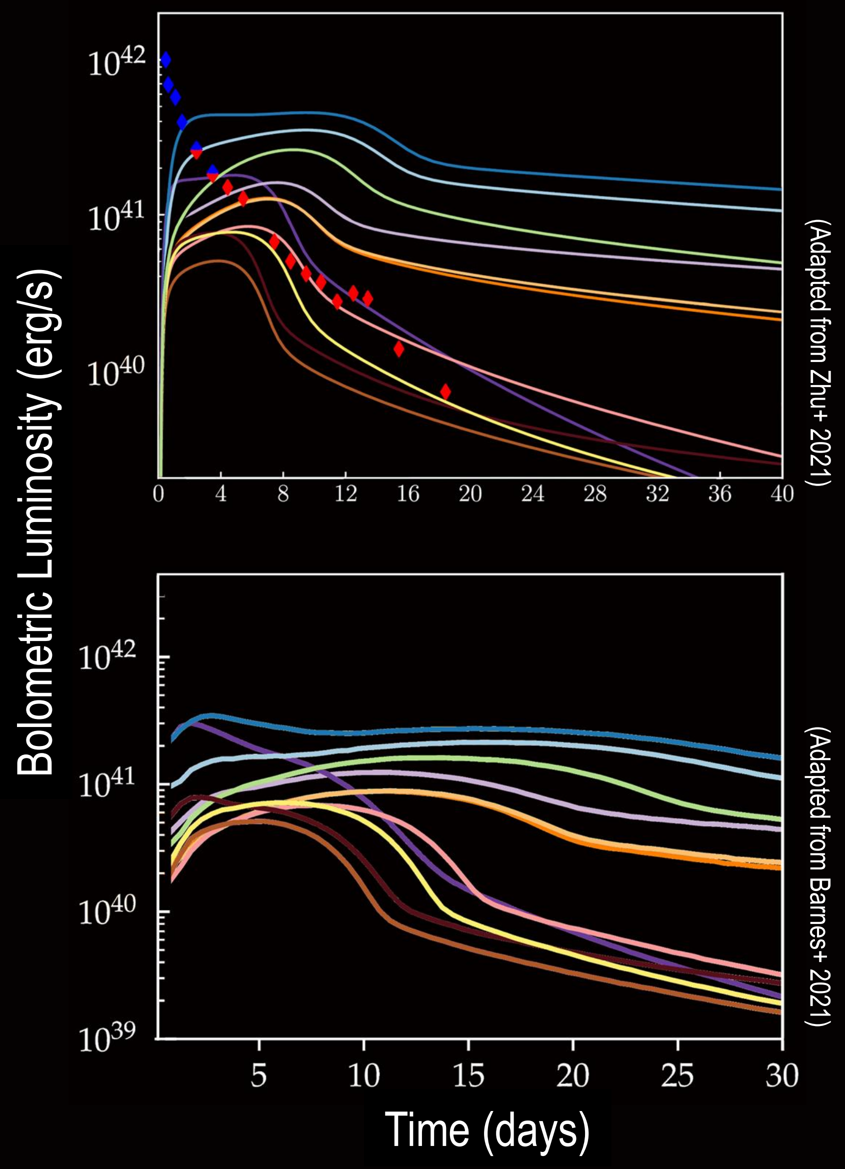
- Fission Yield (x2) (Symmetric; Kodama&Takahashi 1975)

Experimental data is used wherever possible**

**Wang+ (2017), Audi+ (2017)

A large uncertainty in nuclear heating propagates through to a large uncertainty in predictions of light curve shape and magnitude.

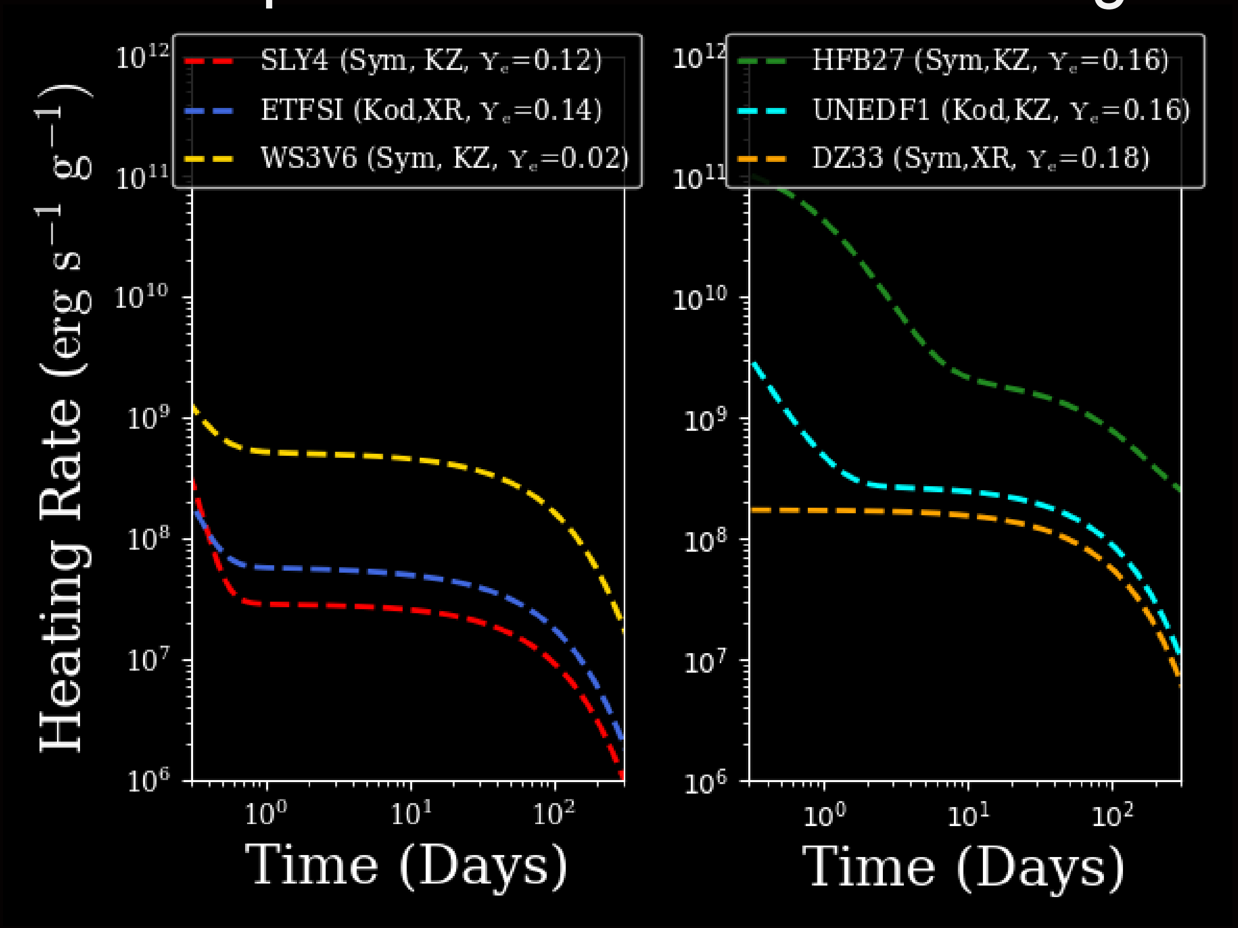
see Zhu+ (2010.03668) and Barnes+ (2010.11182)



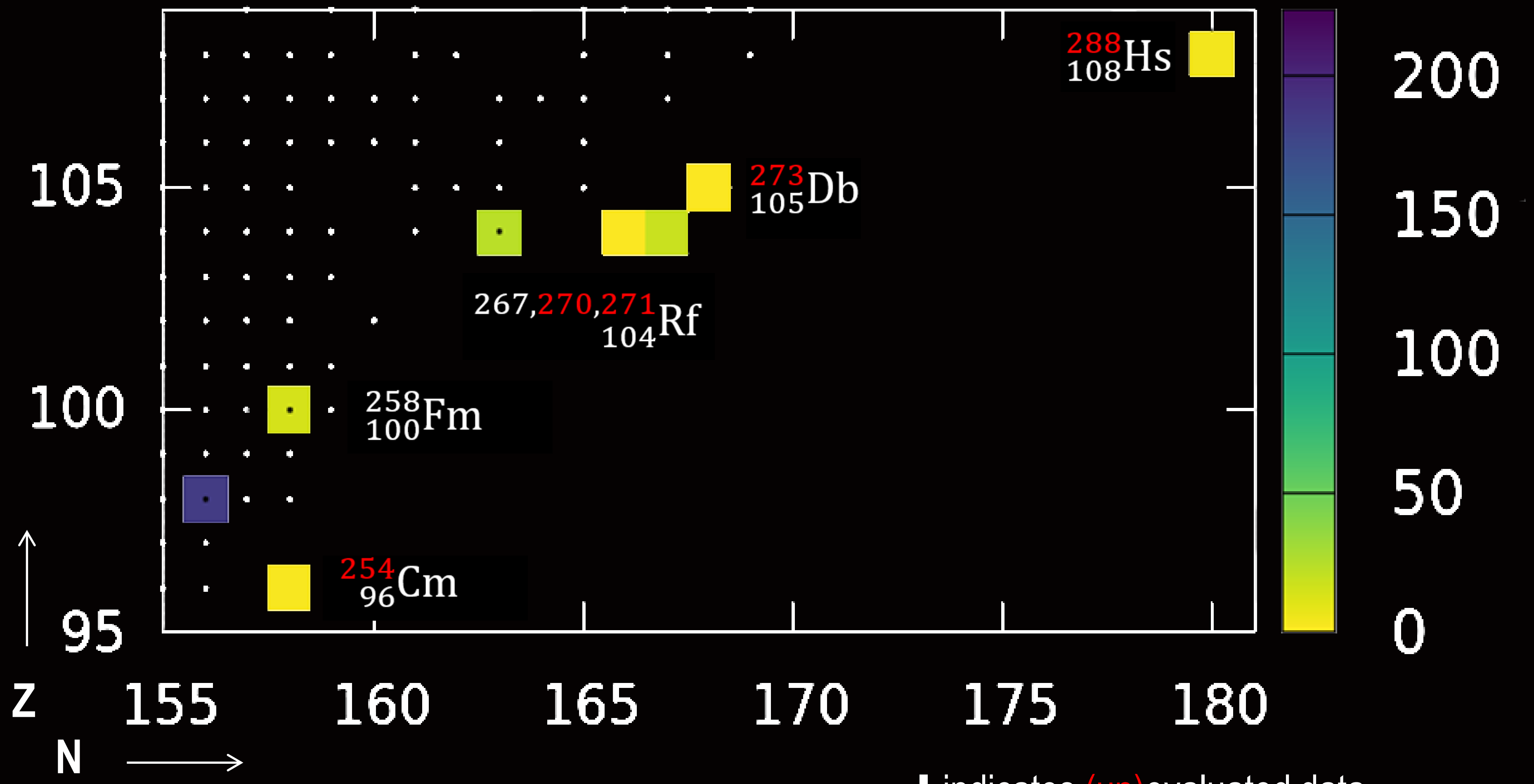
PRISM output allows us to separate contributions from individual channels.

For a subset of models, differences in spontaneous fission heating are immediately apparent.

Spontaneous Fission Heating



Frequency of Top (80%) Contributors to Spontaneous Fission Heating : **1 Day**

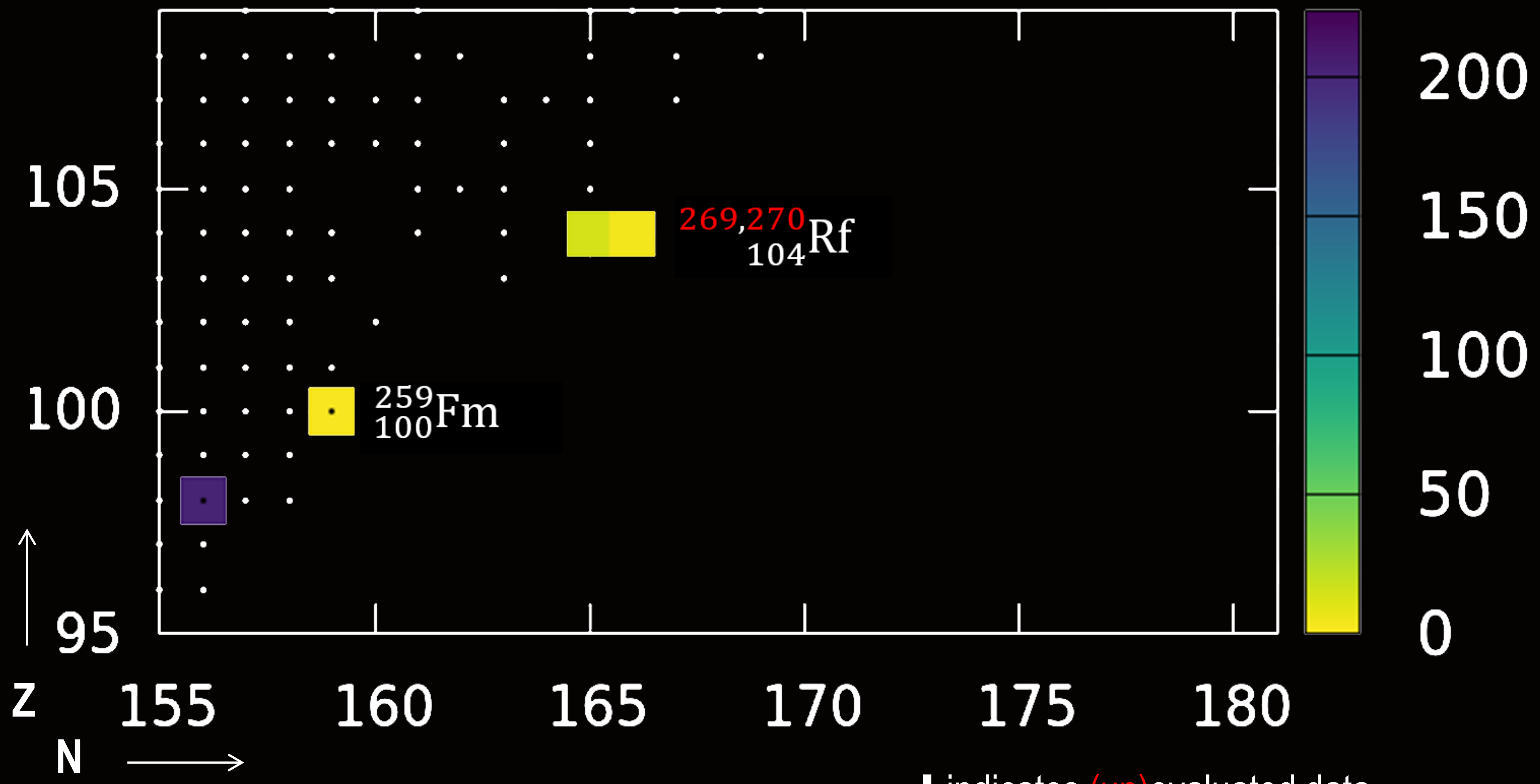


^{254}Cf is consistently present in most of our simulations (see Zhu+ 2018)

Full table in paper: **2010.03668**

▪ indicates (un)evaluated data

Frequency of Top (80%) Contributors to Spontaneous Fission Heating : **8 Days**

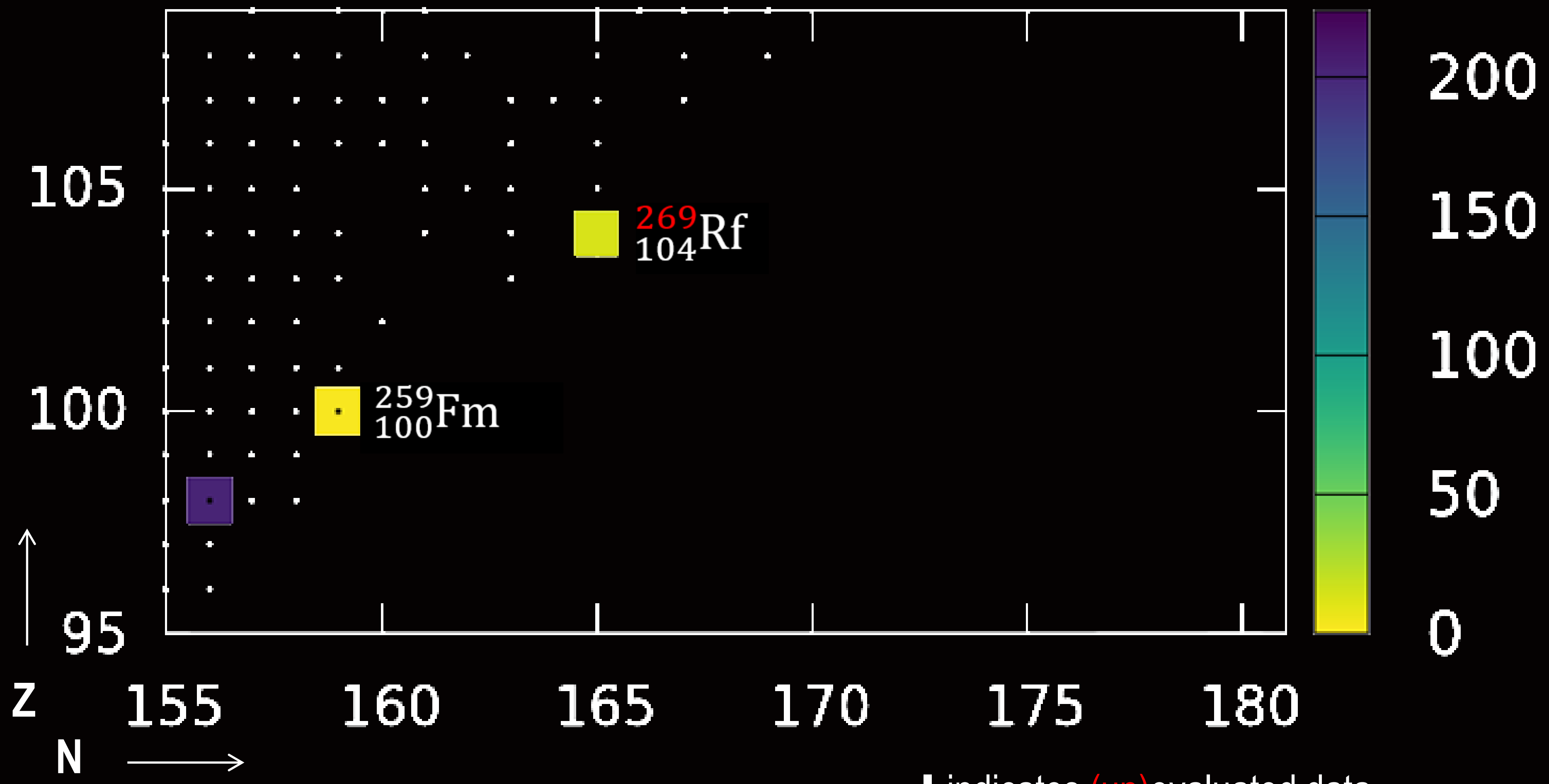


^{254}Cf is still consistently present in most of our simulations (see Zhu+ 2018)

Full table at arXiv: **2010.03668**

▪ indicates (un)evaluated data

Frequency of Top (80%) Contributors to Spontaneous Fission Heating : **50 Days**



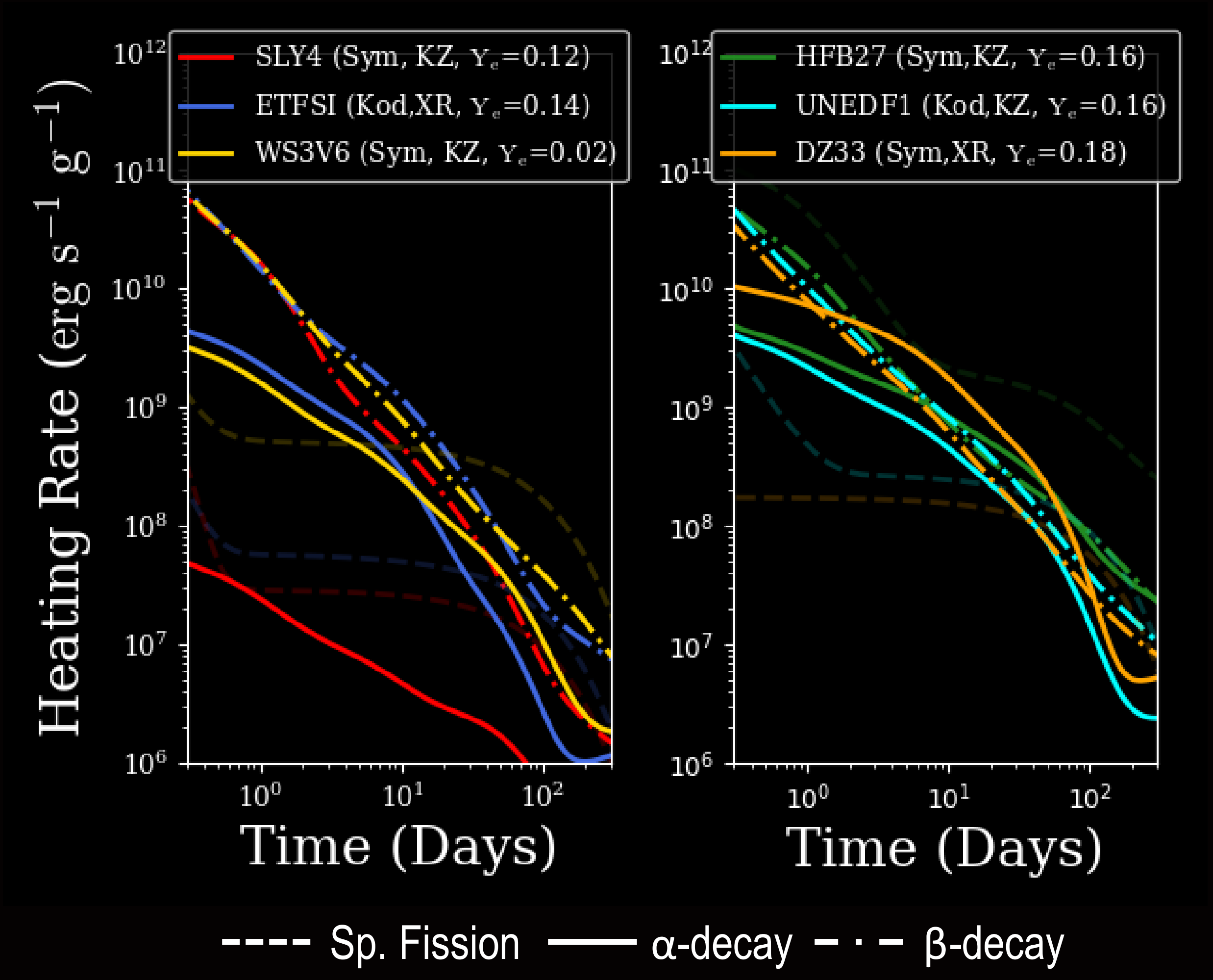
^{269}Rf theoretical half-life and branching ratios vary greatly among models, could be competitive with ^{254}Cf

Full table at arXiv: **2010.03668**

▪ indicates (un)evaluated data

α-decay is also important as it can compete with β-decay and spontaneous fission; it also shows a variety in total heating.

Where do *these* differences come from?



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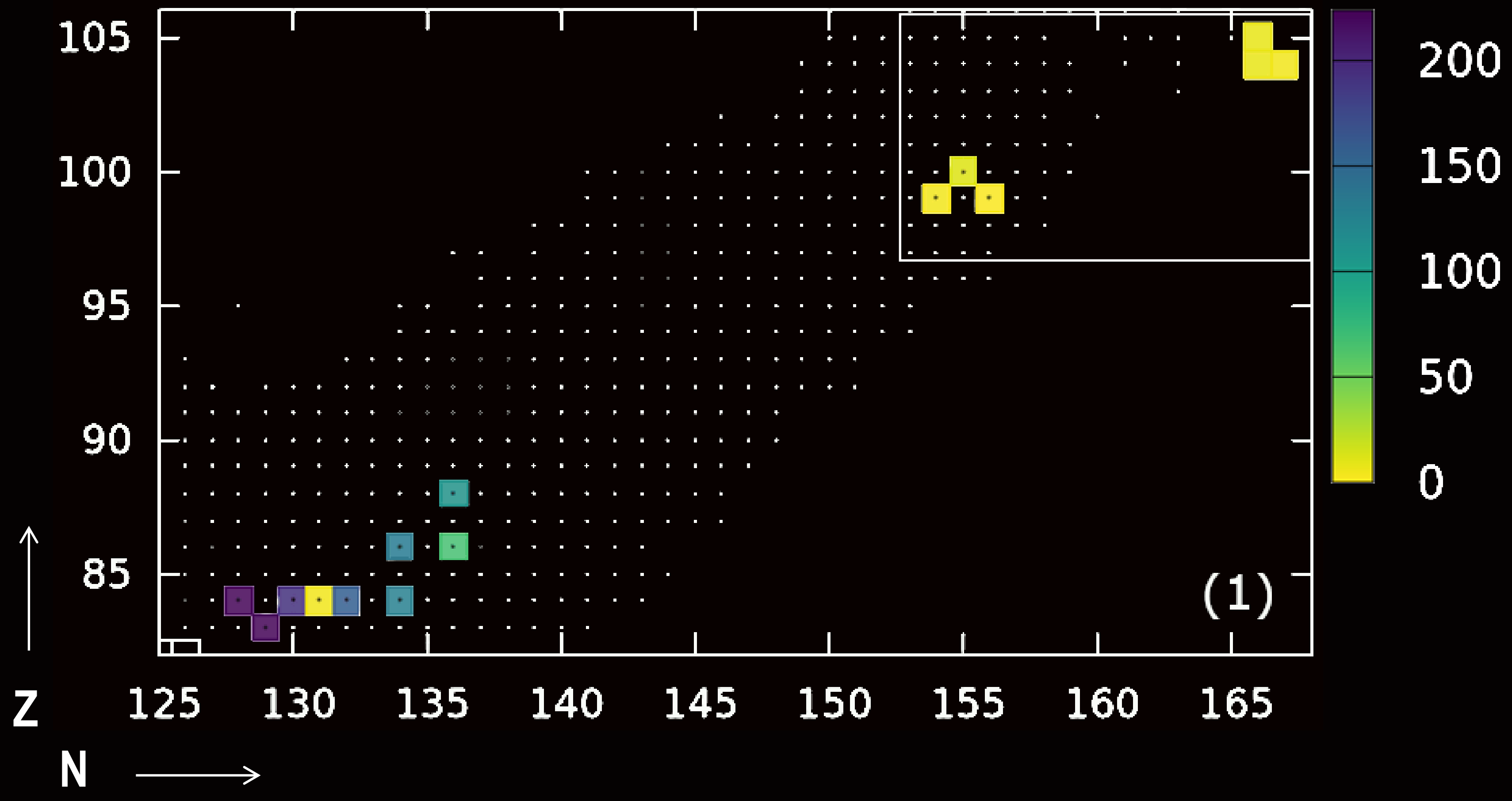
Frequency of Top (80%) Contributors to α-Decay Heating



Potentially important contribution from high-Z α-decay heaters, competition with spontaneous fission:

$^{252}_{98}\mathrm{Cf}$; $^{253,255}_{99}\mathrm{Es}$; $^{255,257}_{100}\mathrm{Fm}$

$^{263,265}_{102}\mathrm{No}$; $^{270,271}_{104}\mathrm{Rf}$; $^{271}_{105}\mathrm{Db}$

Full table in paper

- Changes in theoretical *nuclear model*, *fission rate*, *fission yield*, and Y_e lead to large changes in expected heating from spontaneous fission & α-decay.

- These differences are reflected in diversity of important spontaneous fission heaters at "early" times. Especially sensitive to fission barrier height (HFB).

- Potentially important contribution from α-decay heaters, competition with spontaneous fission (high Z).

- These affect the amount and variety of material that eventually undergoes β-decay towards stability.

(see DOI: 10.3847/1538-4357/abc69e for more detailed tables)

Thank you!

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