Neutron-rich gallium masses and the production of the first r-process peak elements

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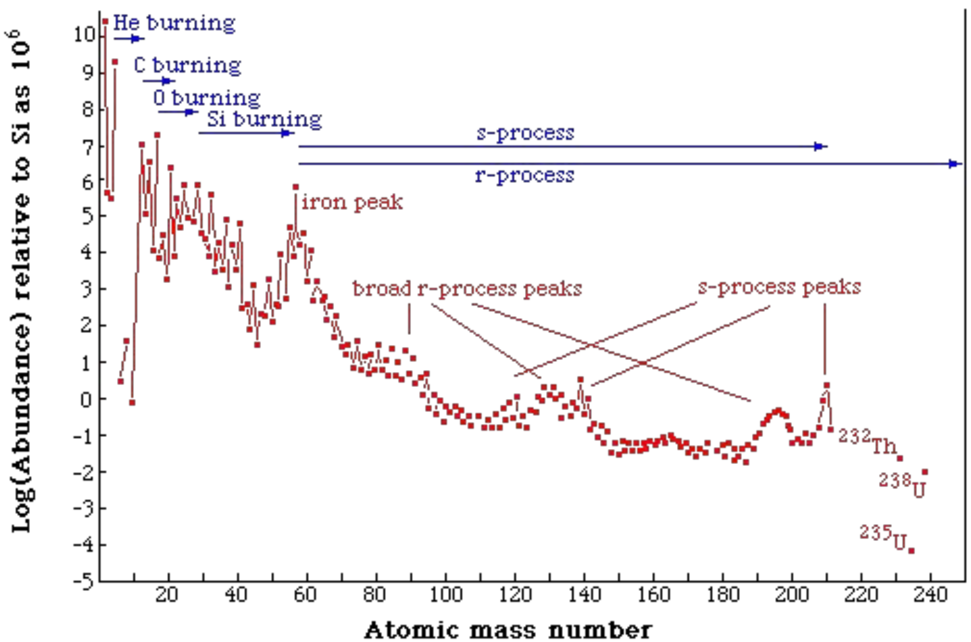
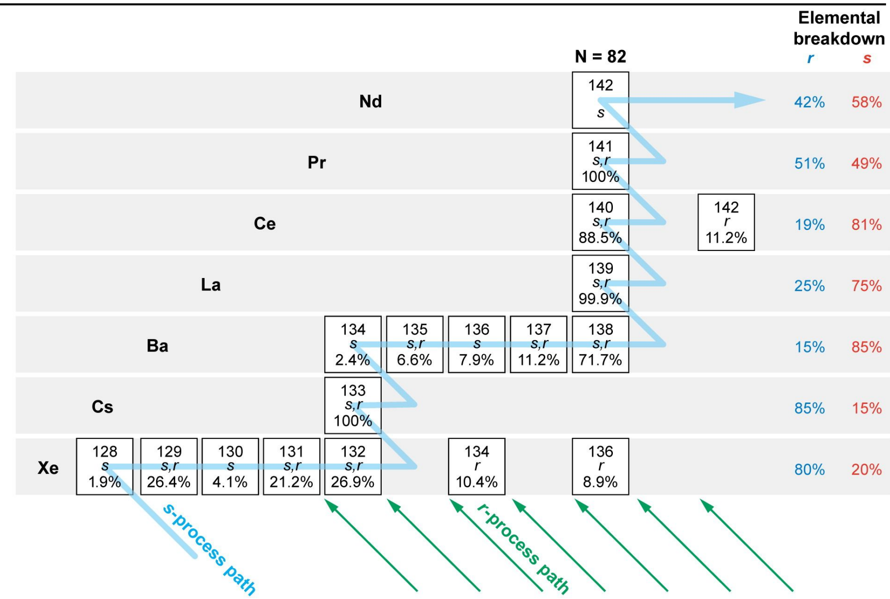
Origin of elements





Sneden C, et al. 2008.
Annu. Rev. Astron. Astrophys. 46:241–88

- Neutron captures drive matter away from stability creating heavier elements thanks to the **s-process & r-process**
- s-process produced elements are well known, deducting their abundances from the solar abundances we end up with the r-process abundances

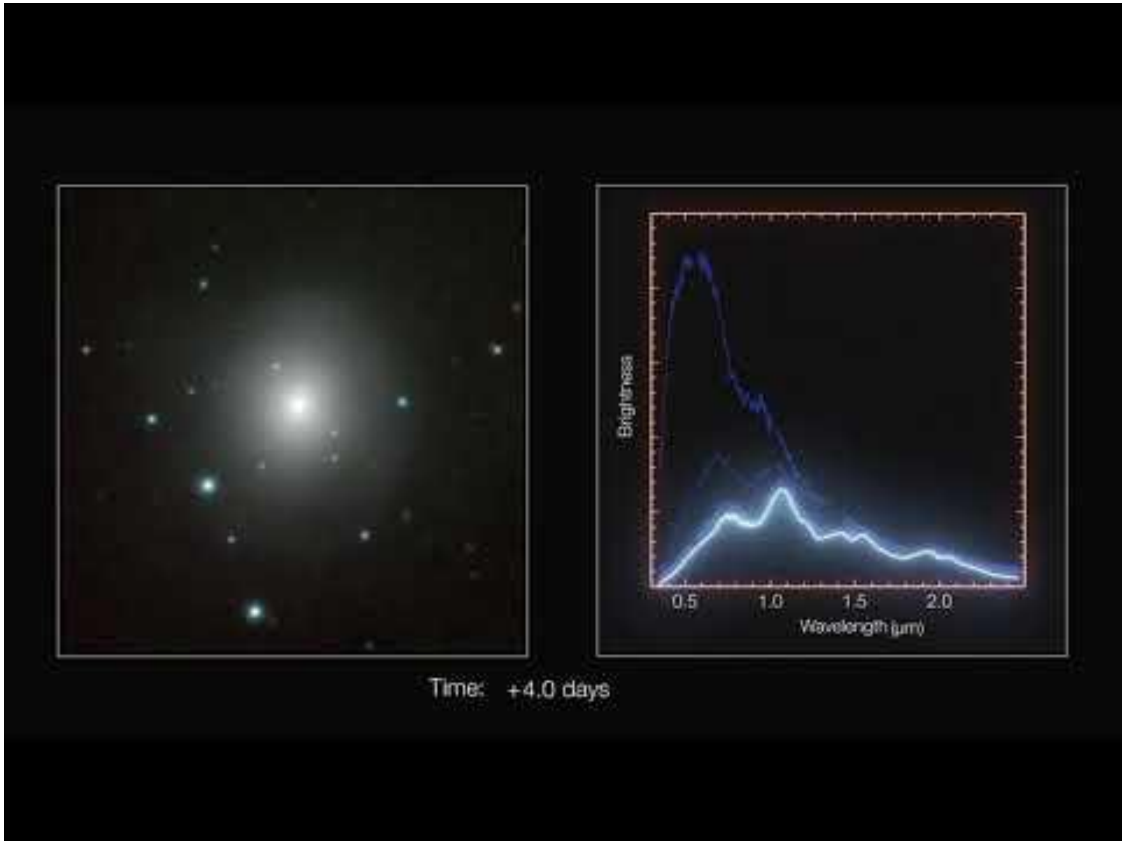
Nucleosynthesis in neutron star mergers: The beginning of multi-messenger era

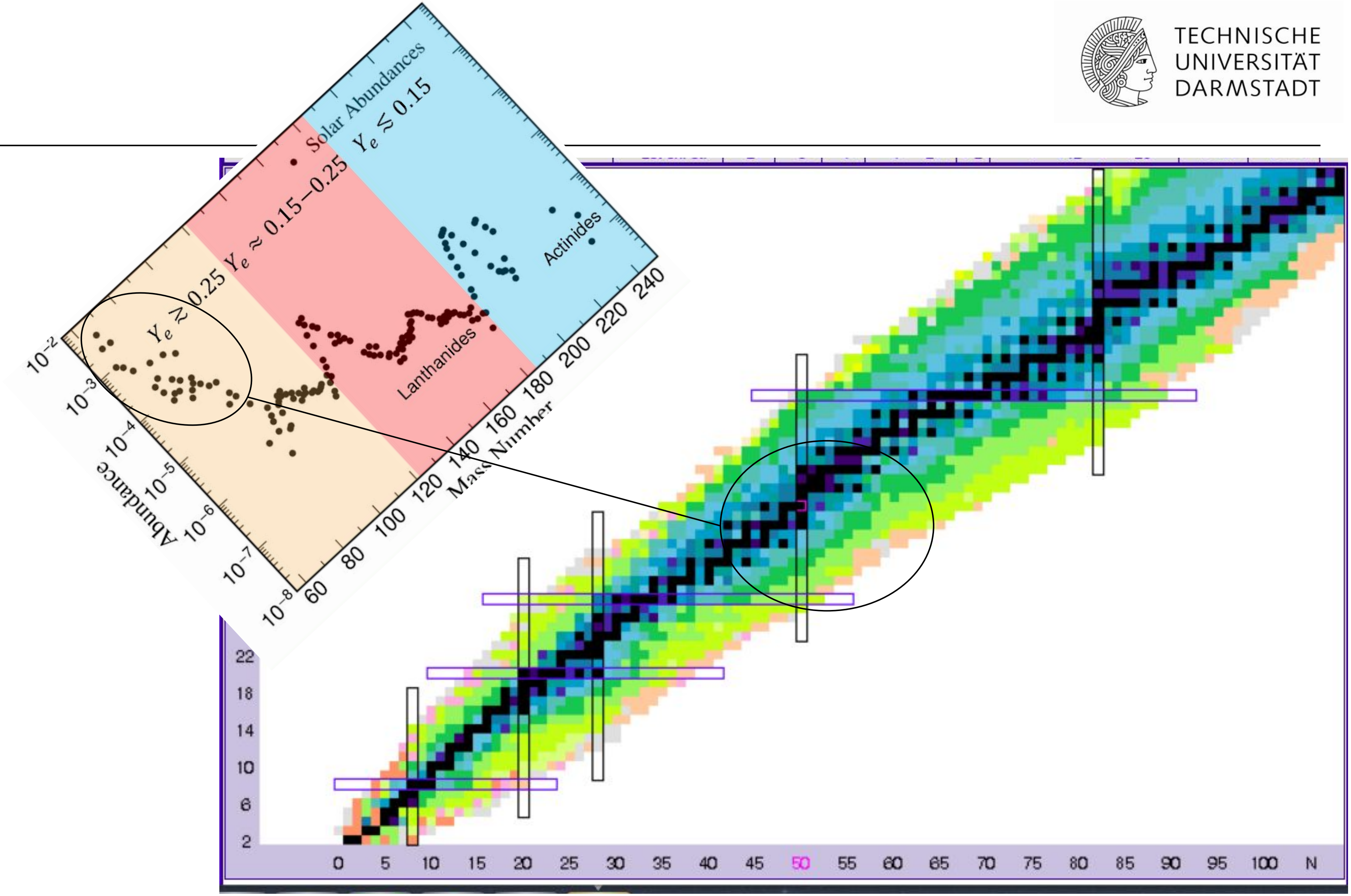
$$Y_e = \frac{p}{n} = \frac{e}{n}$$

Peaks in both Blue and Red exist from the beginning in the spectrum of the EM signal indicating:

- A low Y_e nucleosynthesis site component which corresponds to the red component
- A high Y_e nucleosynthesis site that correspond to the blue component

These 2 different components can be correlated to different nucleosynthesis scenarios.




Solar Abundances
$Y_e \lesssim 0.15$
$Y_e \approx 0.15{-}0.25$
$Y_e \gtrsim 0.25$
Actinides
Lanthanides
Abundance
Mass Number
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 N

Ga mass measurements at TRIUMF

Isotope	mass in u	mass excess /kev	error/kev	error AME /keV	(AME2016 - Exp) /kev
80	79.93644545	-59201	48	2.9	-23
81	80.93814632	-57616	31	3.3	-12
82	81.9431675	-52939	23	2.4	8
83	82.94711887	-49258	25	2.6	1
84	83.95266441	-44093	26	200.0	5
85	84.95733567	-39742	36	300.0	-108

The results of the mass measurements of Ga 80, 81, 82, 83 are close to AME 2016 results confirming previous measurements

The results of the mass measurements of Ga 84,85 are confirming the AME2016 extrapolated values significantly constraining the error bars

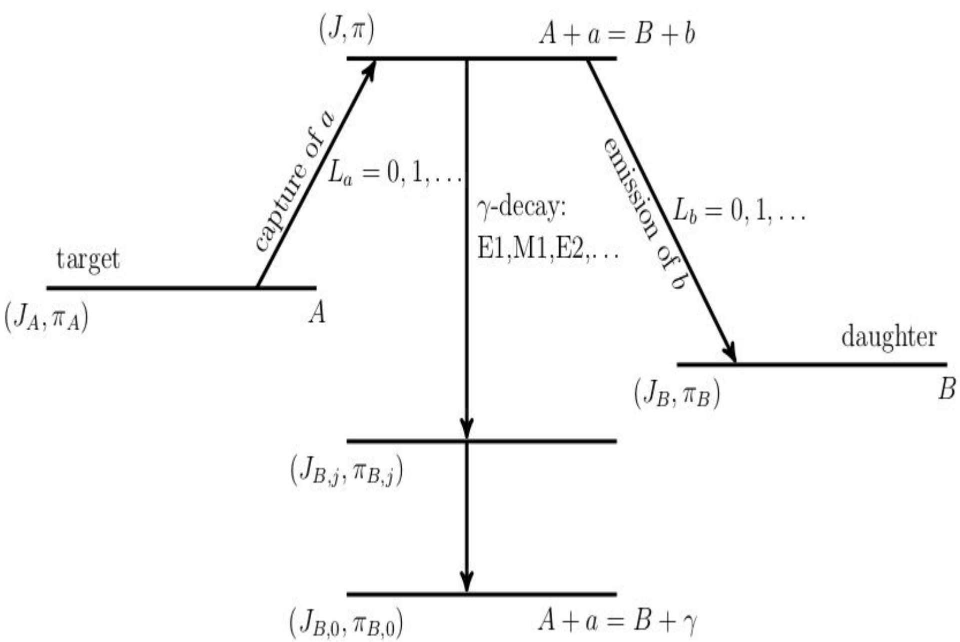
We explore the effects of constraining the Ga 84,85 to reaction rate calculations and elemental abundances calculations

Calculating reaction rates- The Hauser Feshbach statistical model

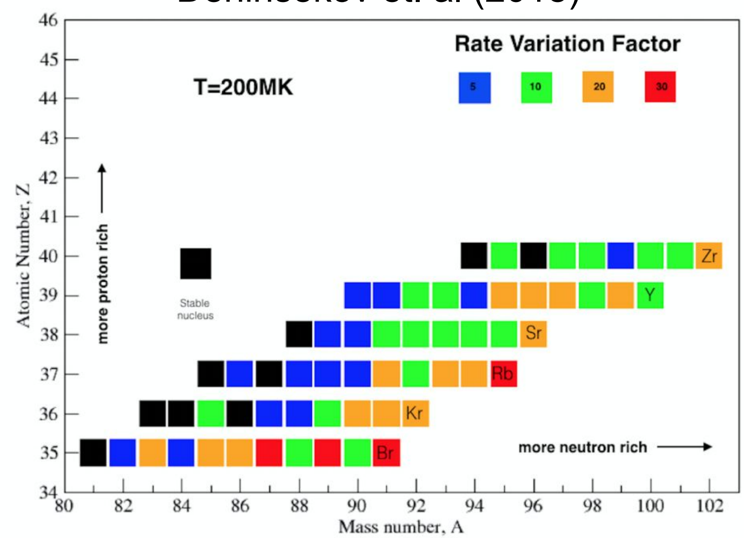
$$\sigma^{\mu}_{n,\gamma}(E) \propto \sum_{J^{\pi}} (2J+1) \frac{T^{\mu}_{n}(J^{\pi}) T_{\gamma}(J^{\pi})}{T_{tot}(J^{\pi})}$$

Important information:

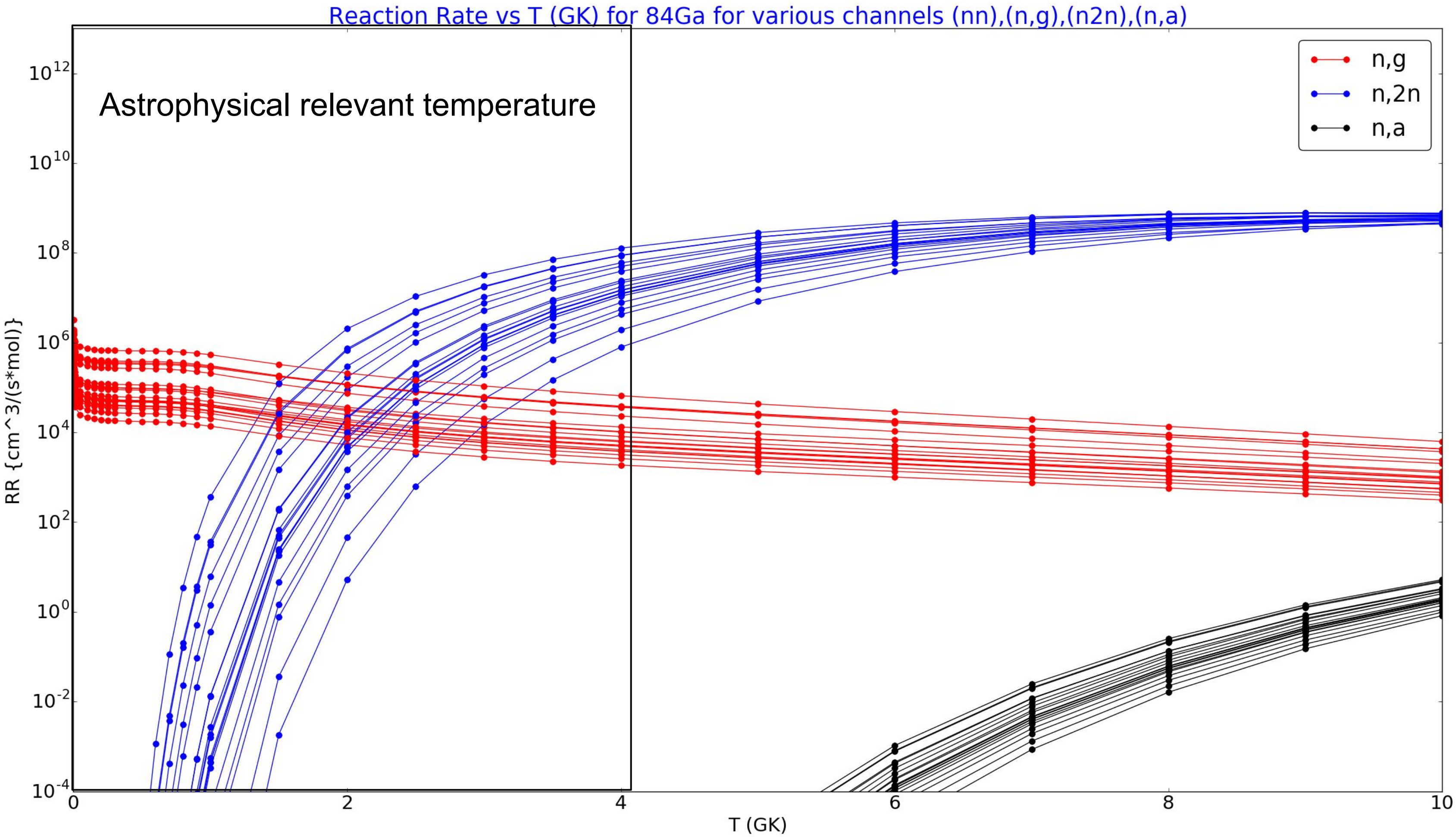
- Masses
- Level densities
- Gamma strength functions
- Optical Potential



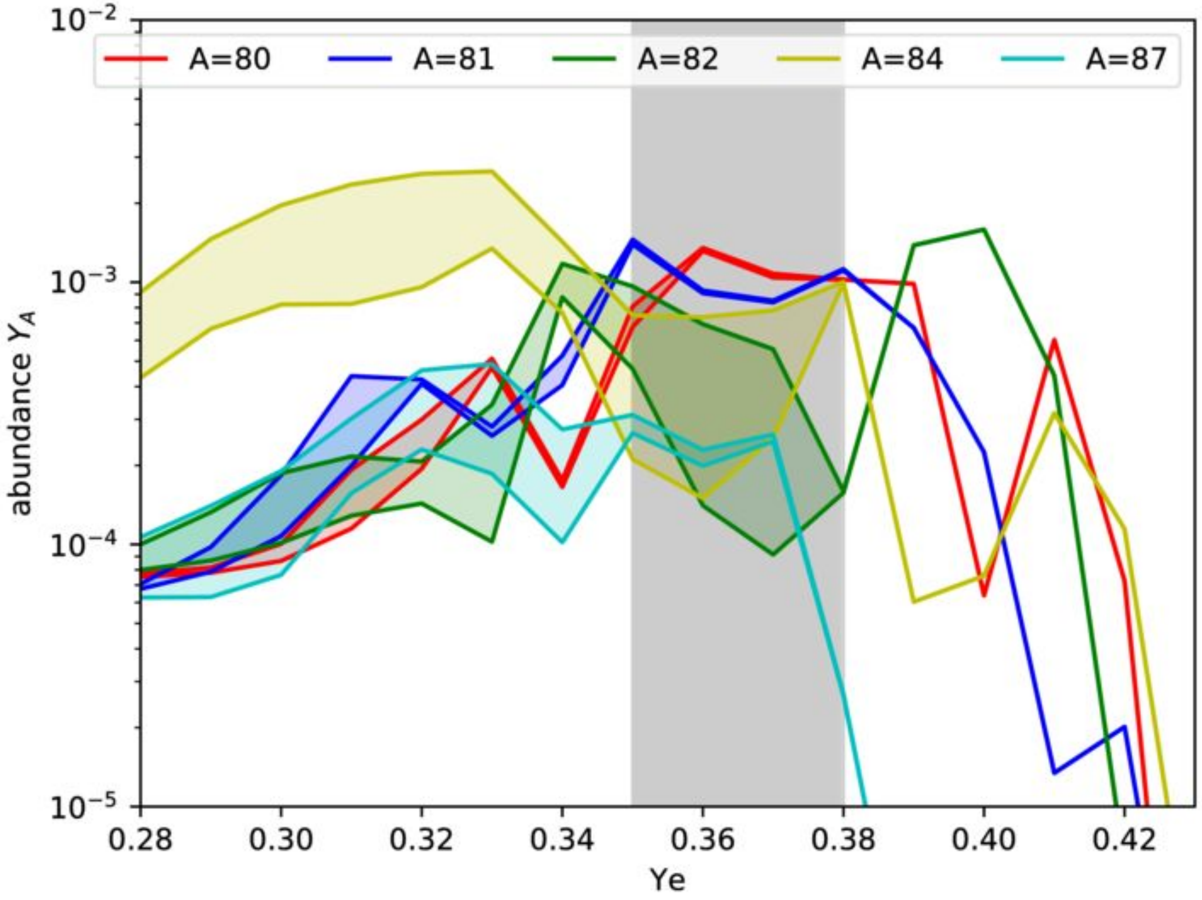
Deninsekov et. al (2018)



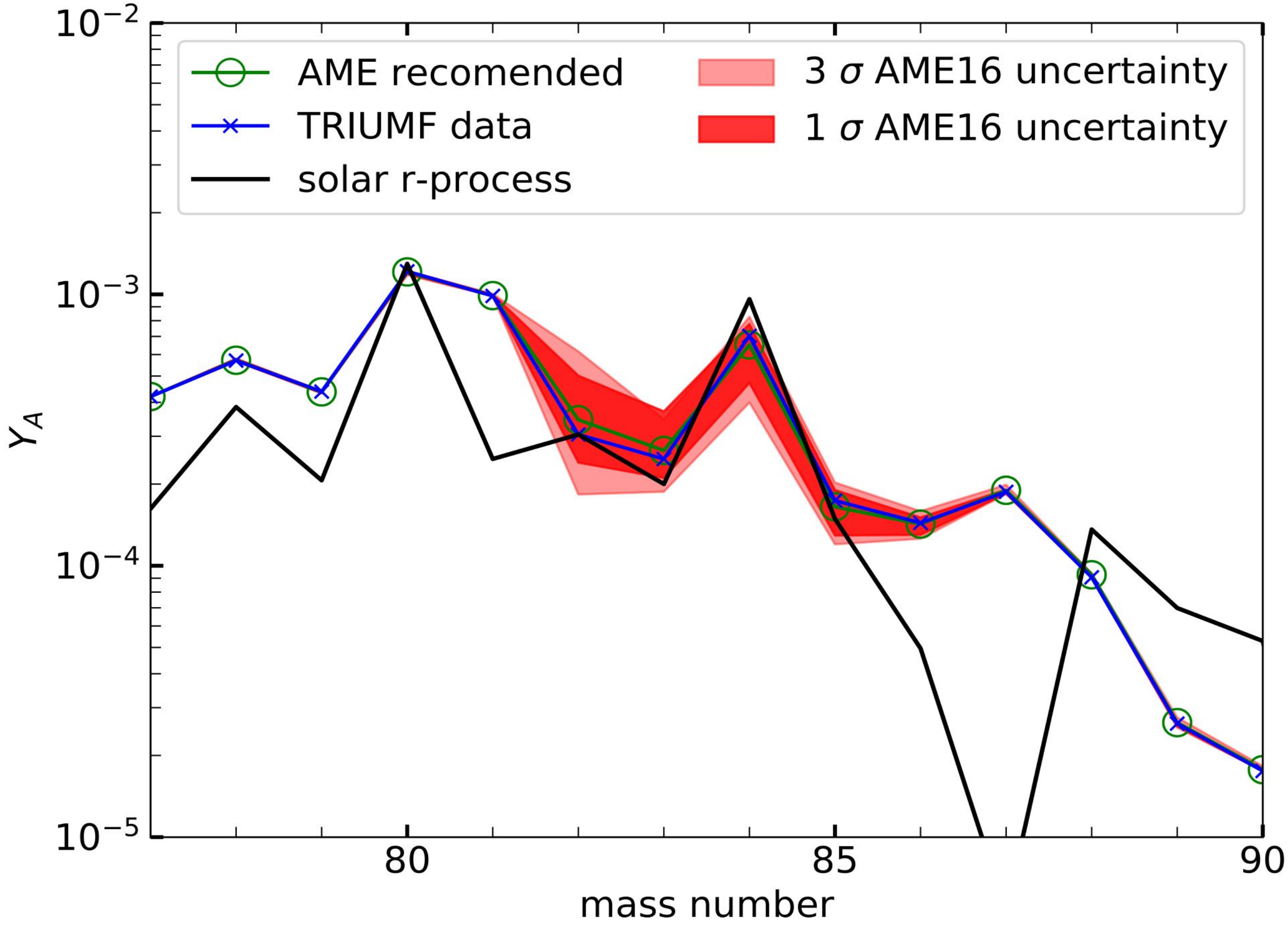
Results of reaction rate calculations within AME 2016 masses errors



Results of the nuclear reaction network

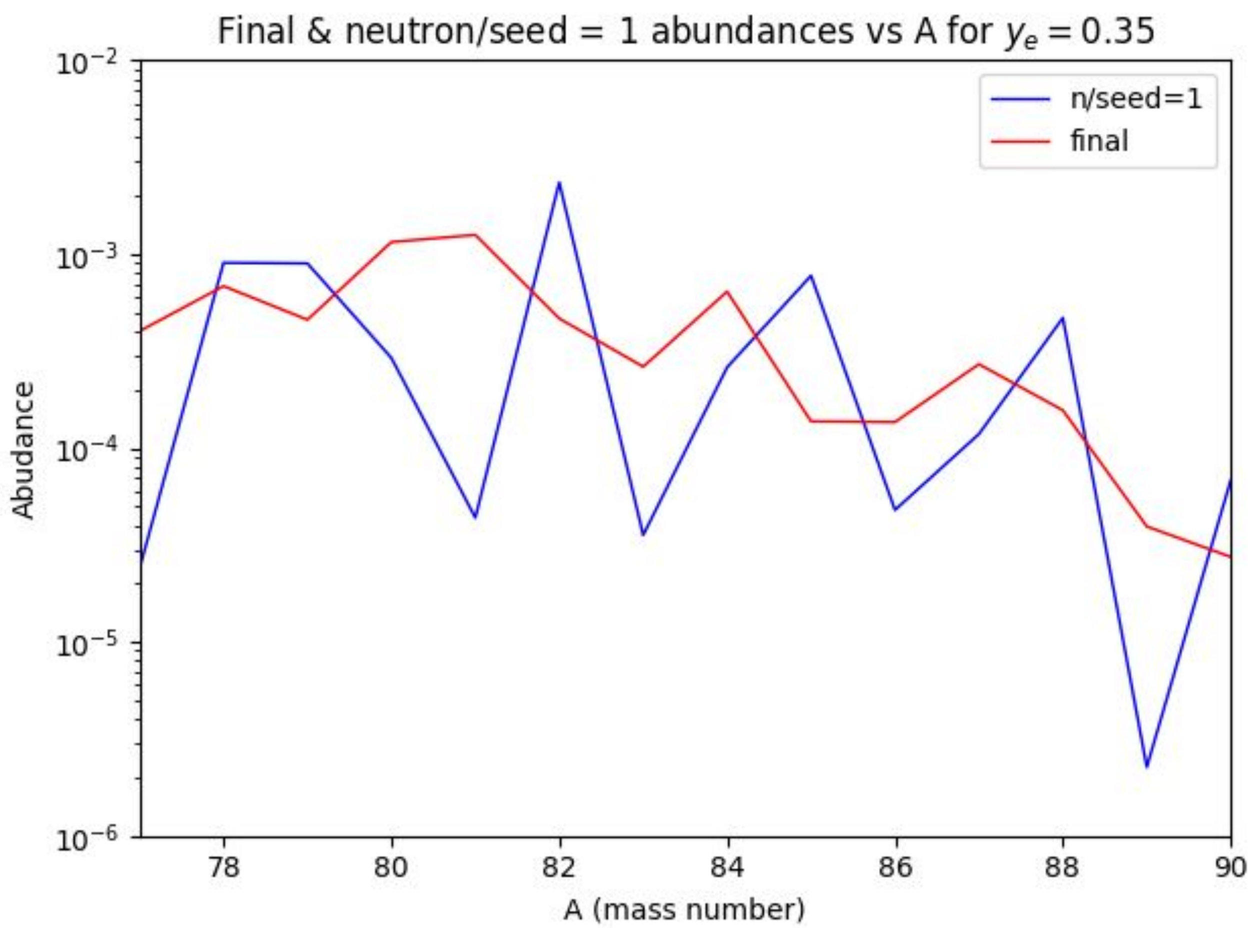


Results of the nuclear reaction network

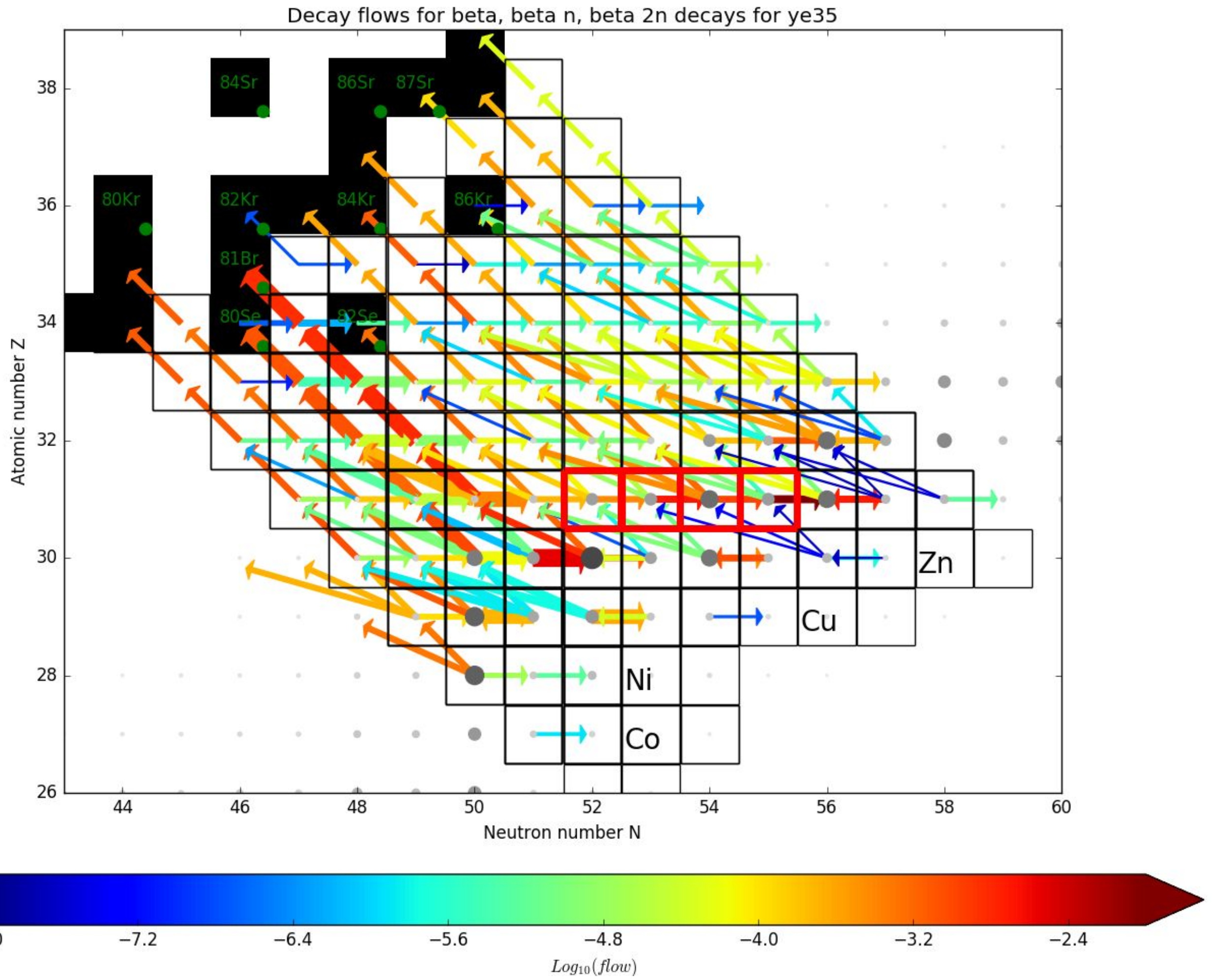


Analysis of reaction network

The different peaks in N/seed=1 and final abundance indicate reshuffling of the material during the decay



Analysis of Reaction Network: path of the r-process, flow diagram



Summary - Thanks - References

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Summarize:

- We were able to evaluate the impact of the 84,85 Ga masses to the r-process abundance pattern
- We identified beta delayed neutron emissions that affect our calculations during the freeze out
- We reproduced part of the r-process abundance pattern.
- Identified where the fine details (local peaks) are originating from
- Provide constraints for the productions of elements with A=84 using the newly measured Ga masses

Support:

SFB 1245

Bundesministerium für Bildung und Forschung

extra1

Core collapse Supernova?
Neutron star merger?
Or both?

Core-Collapse Supernova

Neutron star merger

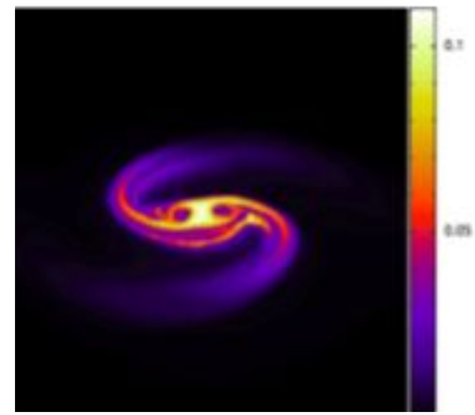
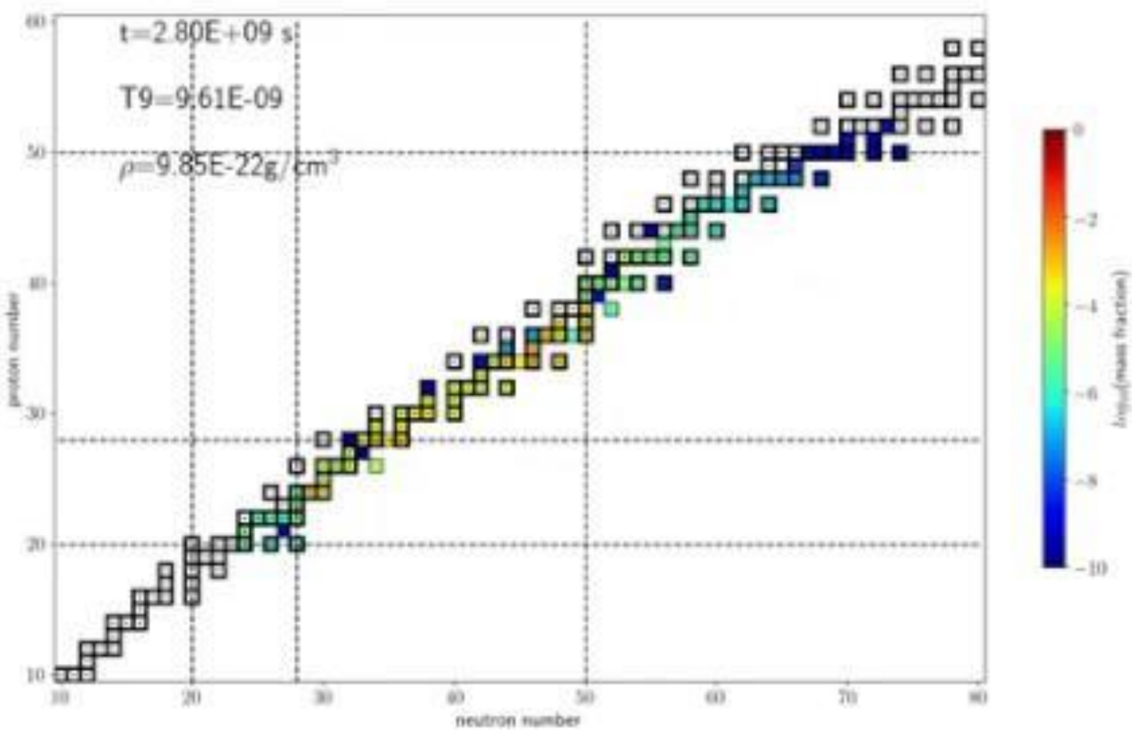


Image credits:NASA-Stephan Rosswog

Conditions (Ye,entropy)	No	Yes
Yield / Frequency	Depends on the astrophysics inputs	Yes
Observation	No	Yes

Final abundances are independent of the astrophysical scenarios and only depend on the nuclear physics inputs

Analysis of reaction network: path of the r-process



Calculation of abundances

A reaction Network calculation requires Nuclear physics and Astrophysical data input.

Nuclear physic inputs contain tabulated data of:

1. Beta decay half lives
2. Neutron separation energies
3. Neutron capture rates etc.

Astrophysical input contains information about:

1. Ye
2. Entropy
3. Temperatures
4. Expansion time

Data and conditions from from :

Huang, W. J., et al. "The AME2016 atomic mass evaluation (I). Evaluation of input data; and adjustment procedures." *Chinese Physics C* 41.3 (2017): 030002.

Audi G, Kondev FG, Wang M, Huang WJ, Naimi S. The NUBASE2016 evaluation of nuclear properties. Chinese Physics C. 2017 Mar;41(3):030001.

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