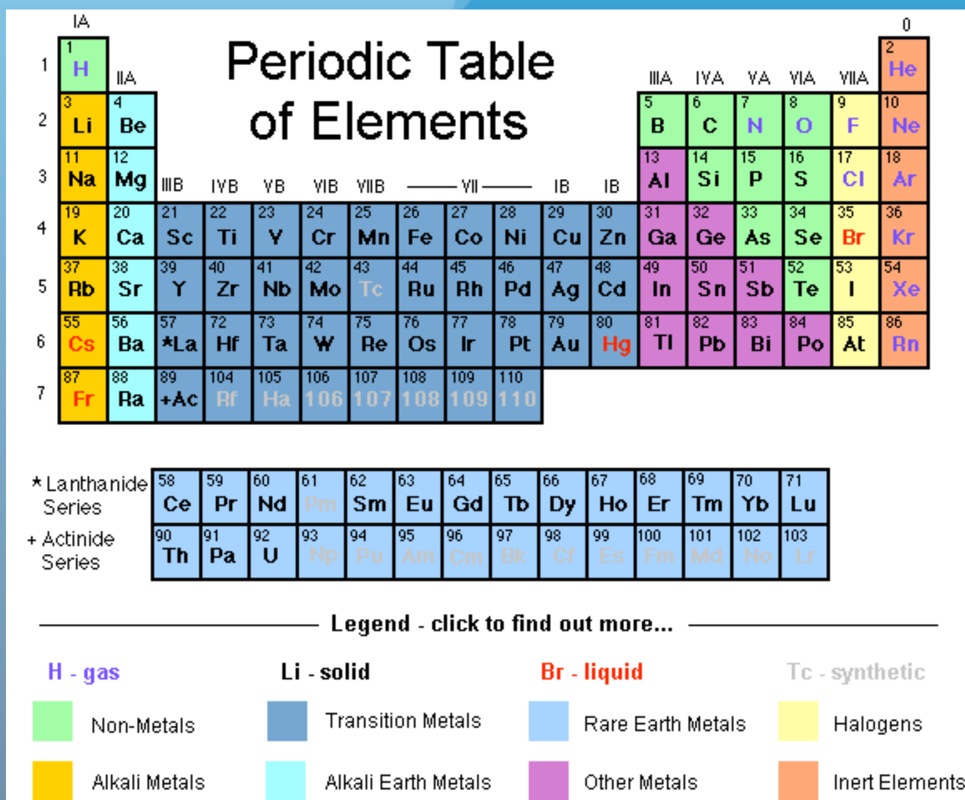
Nucleosynthesis:

Focusing on heavy elements (up to 2003)

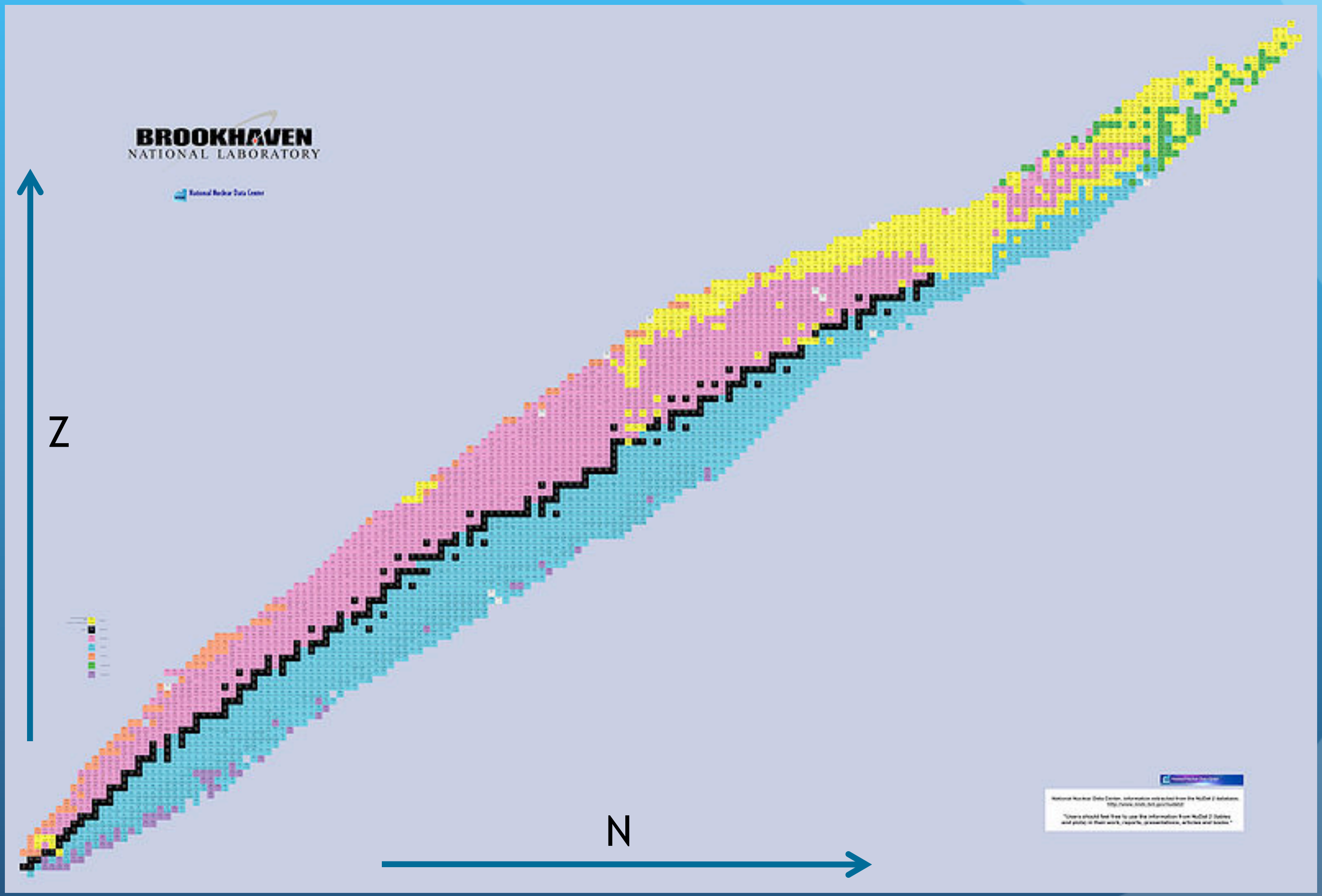


Michael Spillane

Some relevant terms

- β-decay
- N-capture
- Mass number (A)
- Atomic (Proton) number (Z)
- Magic Numbers (for both 2,8,20,28,50,82 and for neutrons 126)

Map of stable nuclei



History

- In the 1920's Arthur Eddington suggested that the sun runs on fusion
- Just before WWII Hans Bethe determines a mechanism for the creation of ^4He
- The Big Bang as the source of all nuclei
- In 1956 a new and much improved experimental data was published on abundances of nuclei (Suess, Urey)

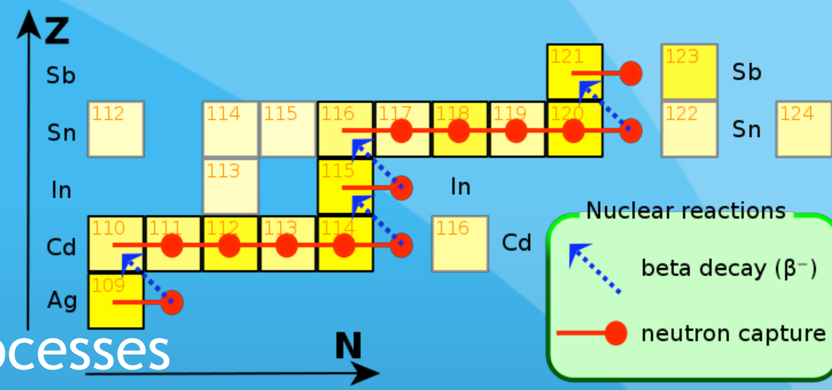
B^2FH

- This paper marked the start of stellar

nucleosynthesis

- Rejected Big Bang as source of nuclei
- Divide all of the elements into two major subgroups (s-process and r-process)

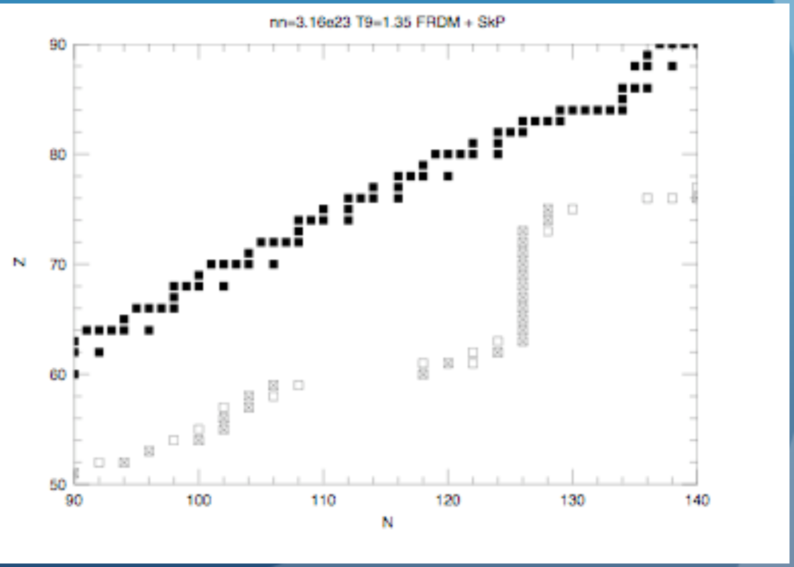
S-process



- Best understood of the processes
- Slow is defined as $\tau_b < \tau_n$
- A neutron is captured by a nucleus it then β-decays into a stable nuclei
- Because of this the s-process creates those nuclei that are near stability
- The only suspected location is in Asymptotic Giant Branch stars (AGB)

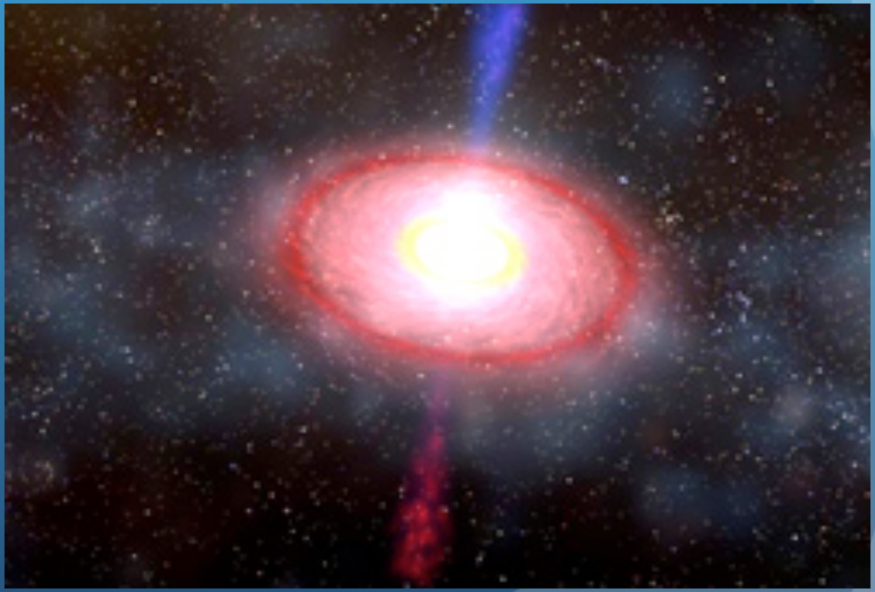
R-process

- By definition $\tau_n << \tau_b$
- The best current model is called the waiting point approximation
- Typical temperatures ~ 10^9 K and neutron densities $>10^{20}$ cm^{-3}



R-process sites

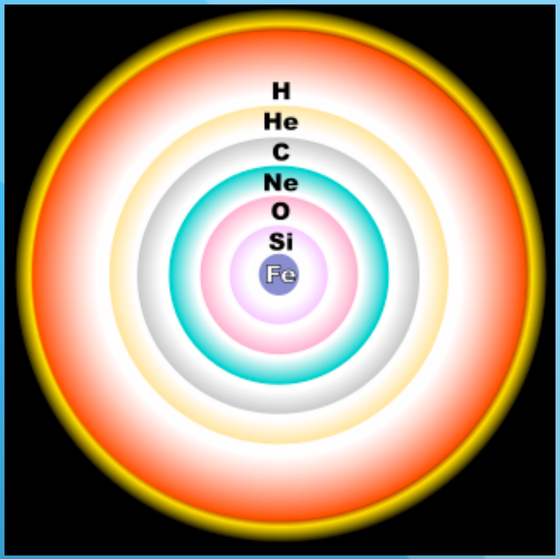
- Core collapse supernova
- Neutron star mergers



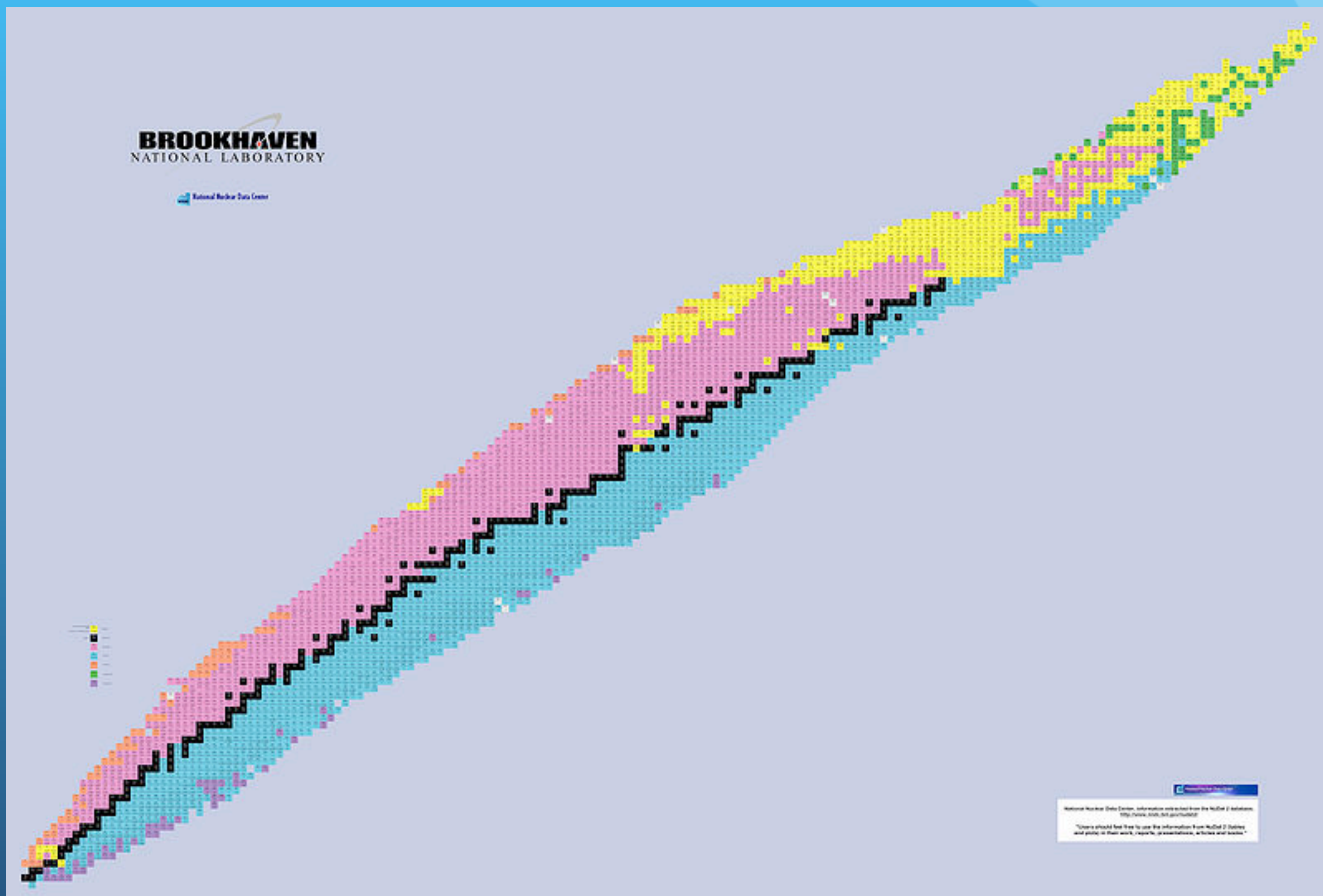
P-process

- There are 35 neutron deficient nuclei for A>70 some of these can be made through the s-process
- This method also relies on photodisintegration of s-process seeds (s-nuclei)
- Certain elements are under produced using this method for the p-process
- Adding neutrinos will fix some problems but not all
- Increasing the number of s-nuclei present also could help

P-process sites



- O/Ne layer in highly evolved massive stars
- X-ray novae
- Neutrino driven winds originating from supernova
- Super critical accretion disks (SSAD's) around a star following supernova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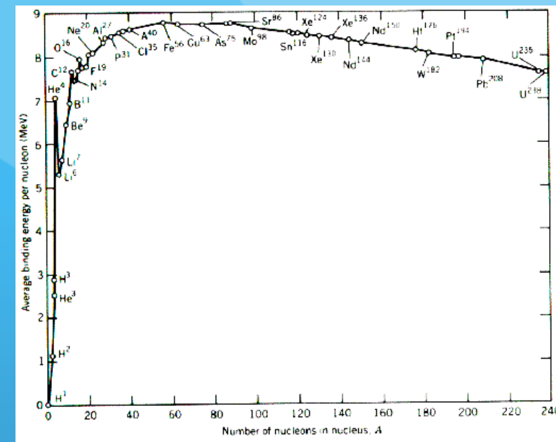
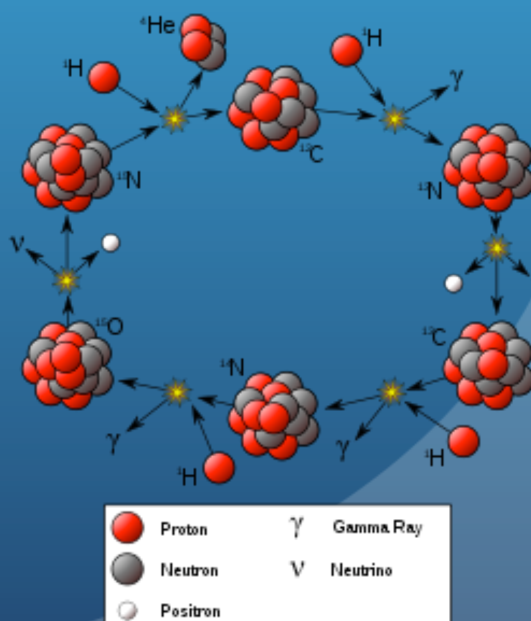
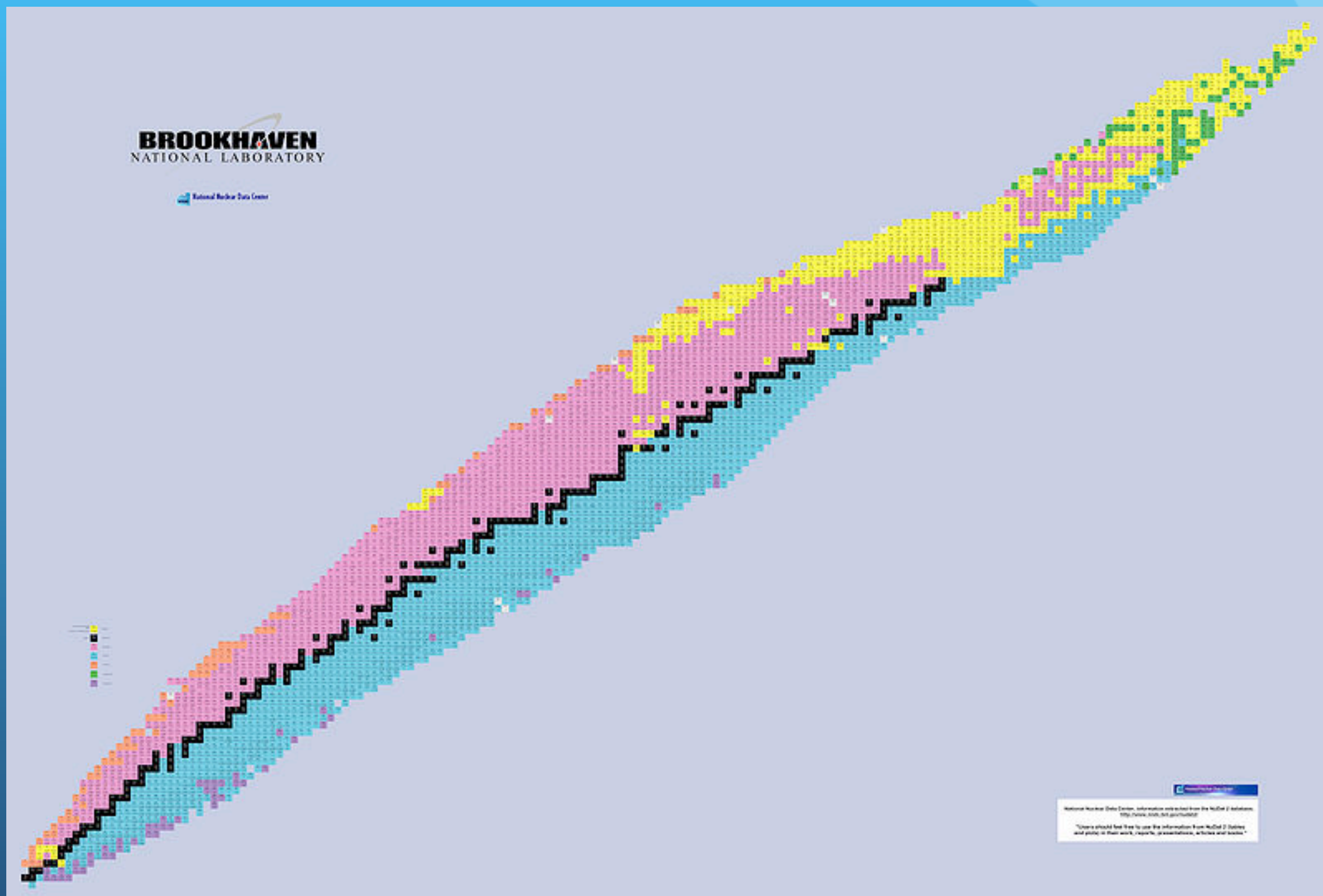
Creation of nuclei A<56



- Big Bang (H, He, Li)
- Nuclear fusion generally of ^{4}He (α-particles)
- To produce intermediate elements s-process
- Cosmic ray spallation

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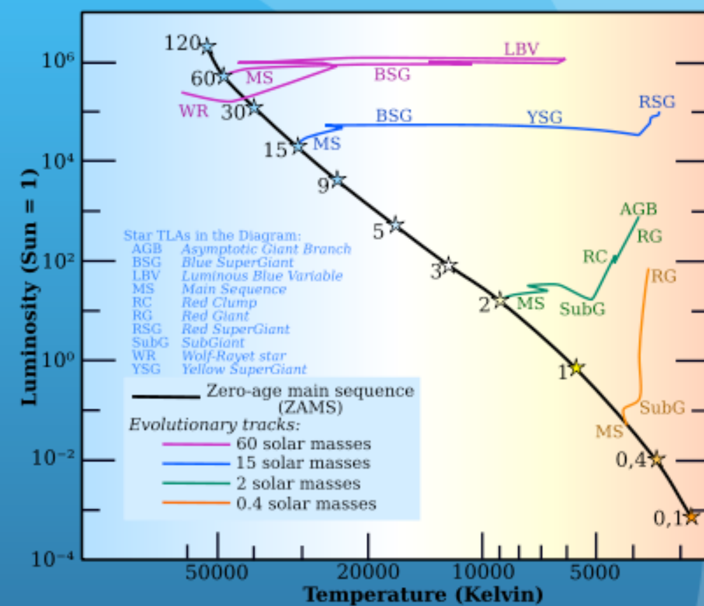
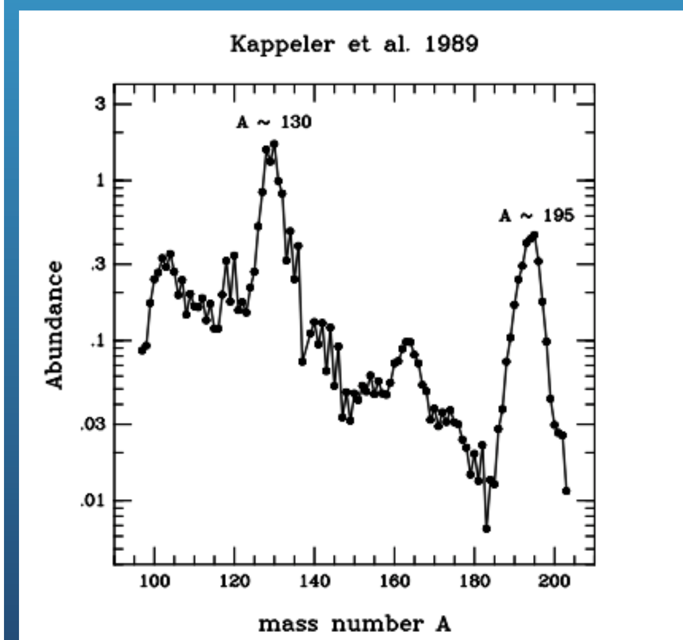
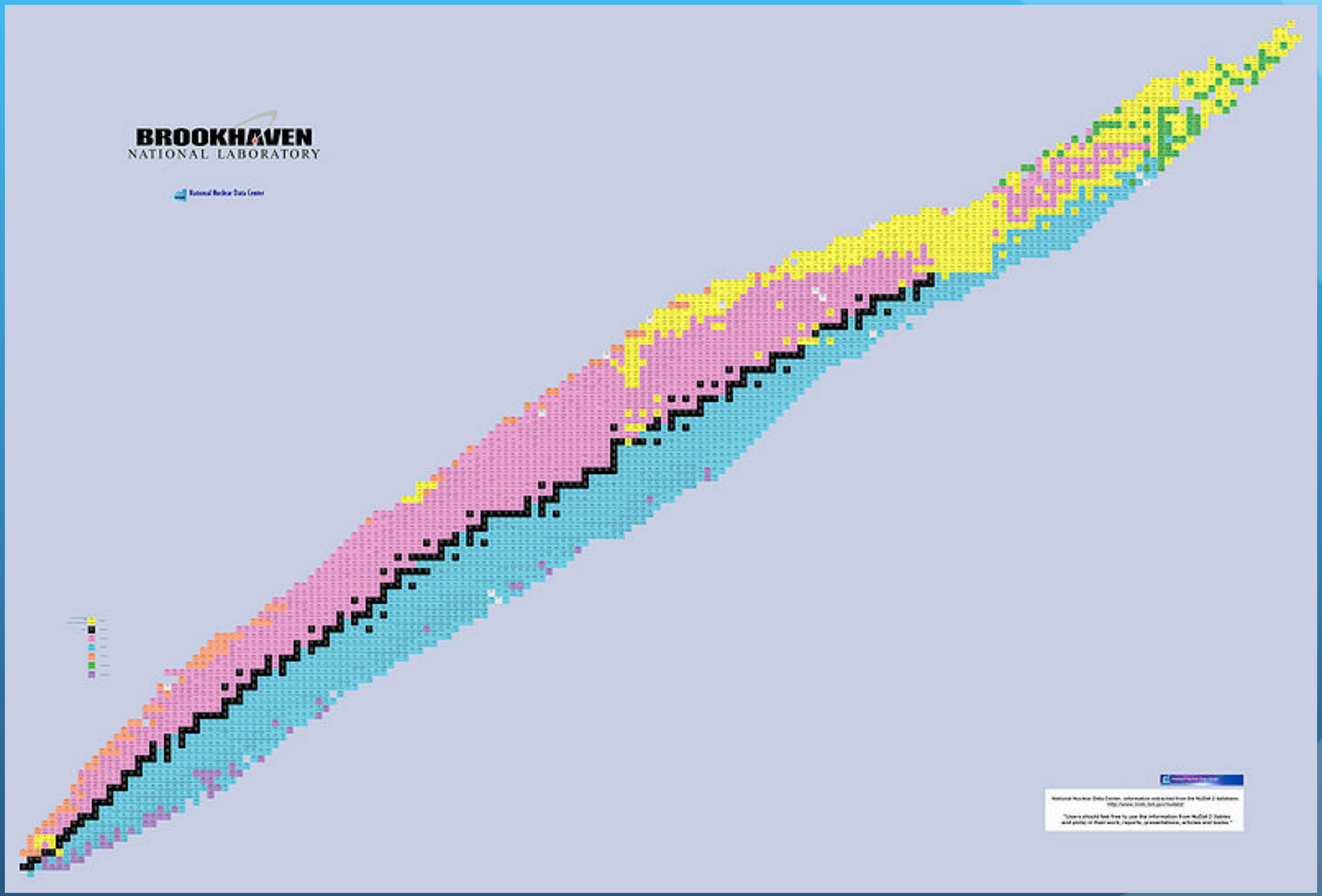
Creation of nuclei 56<A<130

- S-process creates those near stability (AGB stars)
- R-process creates another 50% relevant magic number is N = 82





•P-process creates most of the neutron deficient isotopes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Creation of nuclei A>130

- S-process continues to make elements near stability with mass numbers up to A = 204
- R-process creates those far from stability, but there are problems with creation sites (relevant magic number N =126)
- Humans have manufactured some elements not found in nature with Z up to 103

Conclusions

- Models which have existed since the 1950's provide excellent qualitative explanations of of abundance data
- The models however fail on describing the finer points of the abundance data
- More information is needed about masses, cross sections, and b-decay rates for nuclei far from stability
- Also better models are needed for supernova and their production of neutrinos