Daddy, where did I come from?

Jeremy Heyl

18 July 2018

Big-Bang Nucleosynthesis

- Alpher, Bethe and Gamov (1948) argued that all of the elements were produced in the early Universe,
- The nuclei built up through neutron capture in the "overheated neutral nuclear fluid."
- The neutrons started to stick to each other about 20 seconds after the start of time.

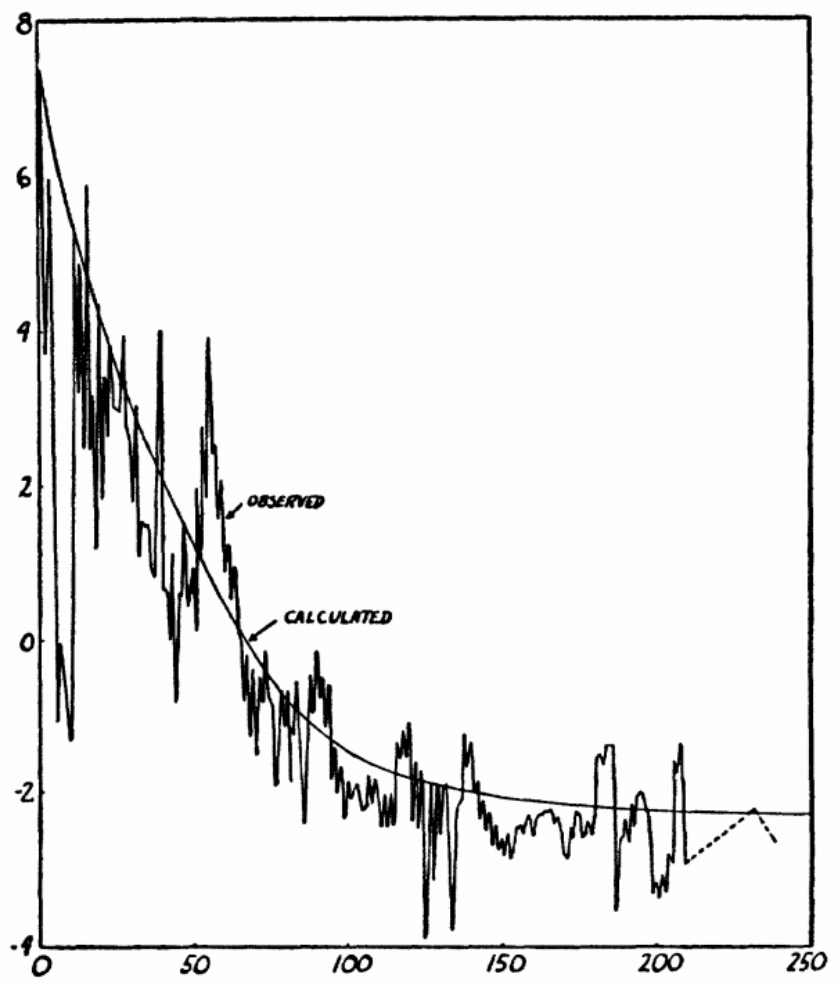
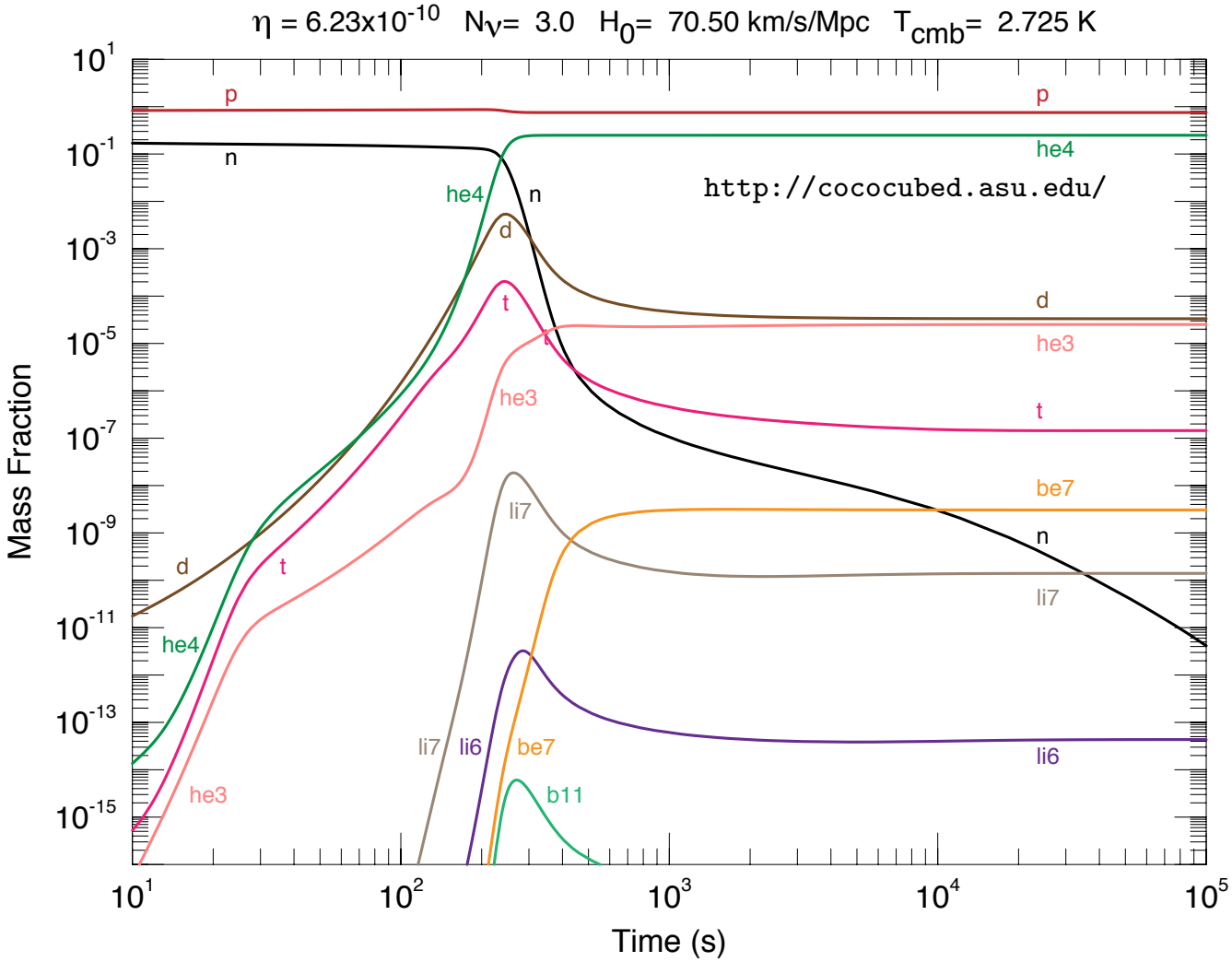


FIG. 1.

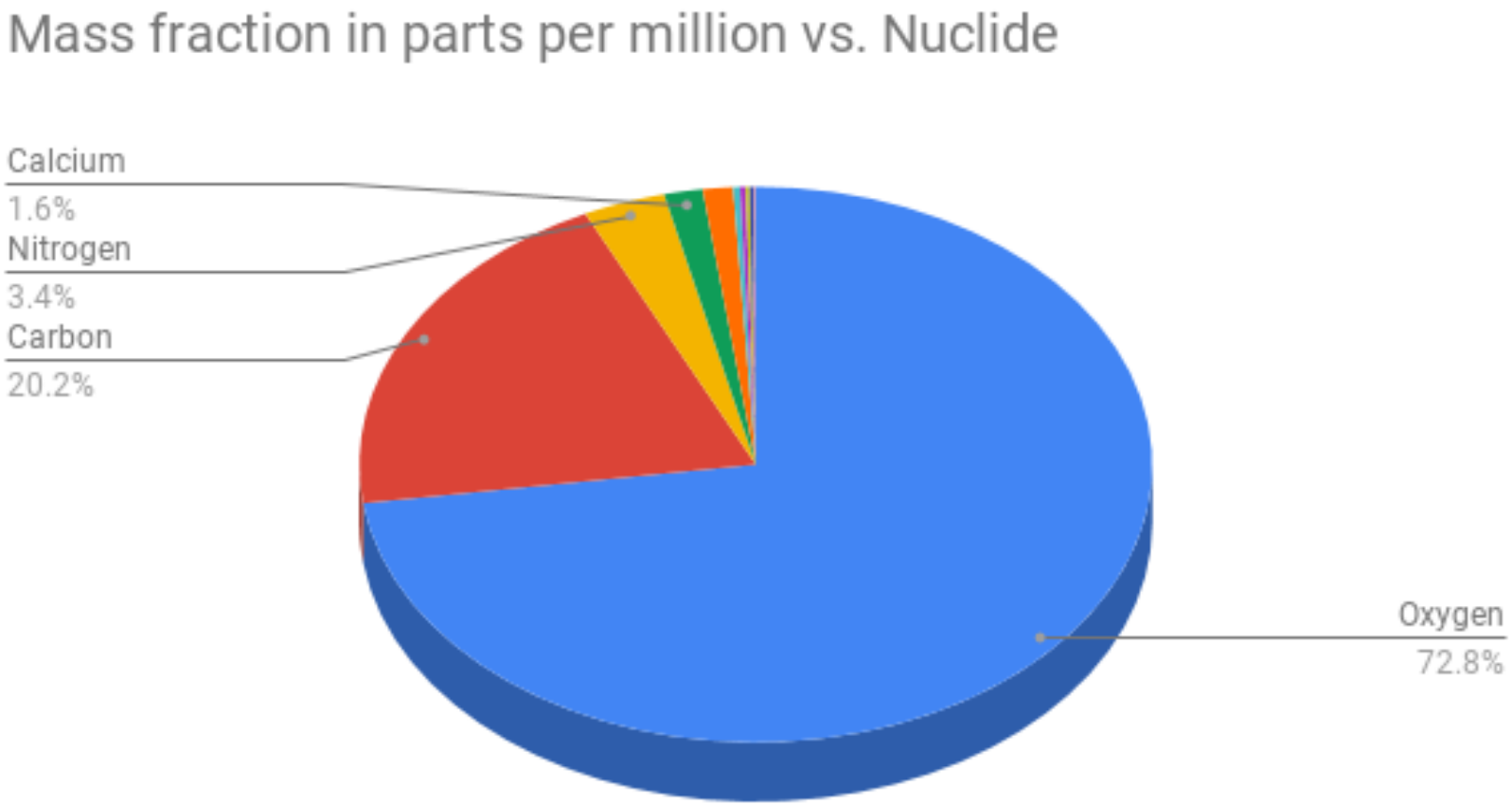
Log of relative abundance

Atomic weight

Big-Bang Nucleosynthesis



The Abundance of the Elements



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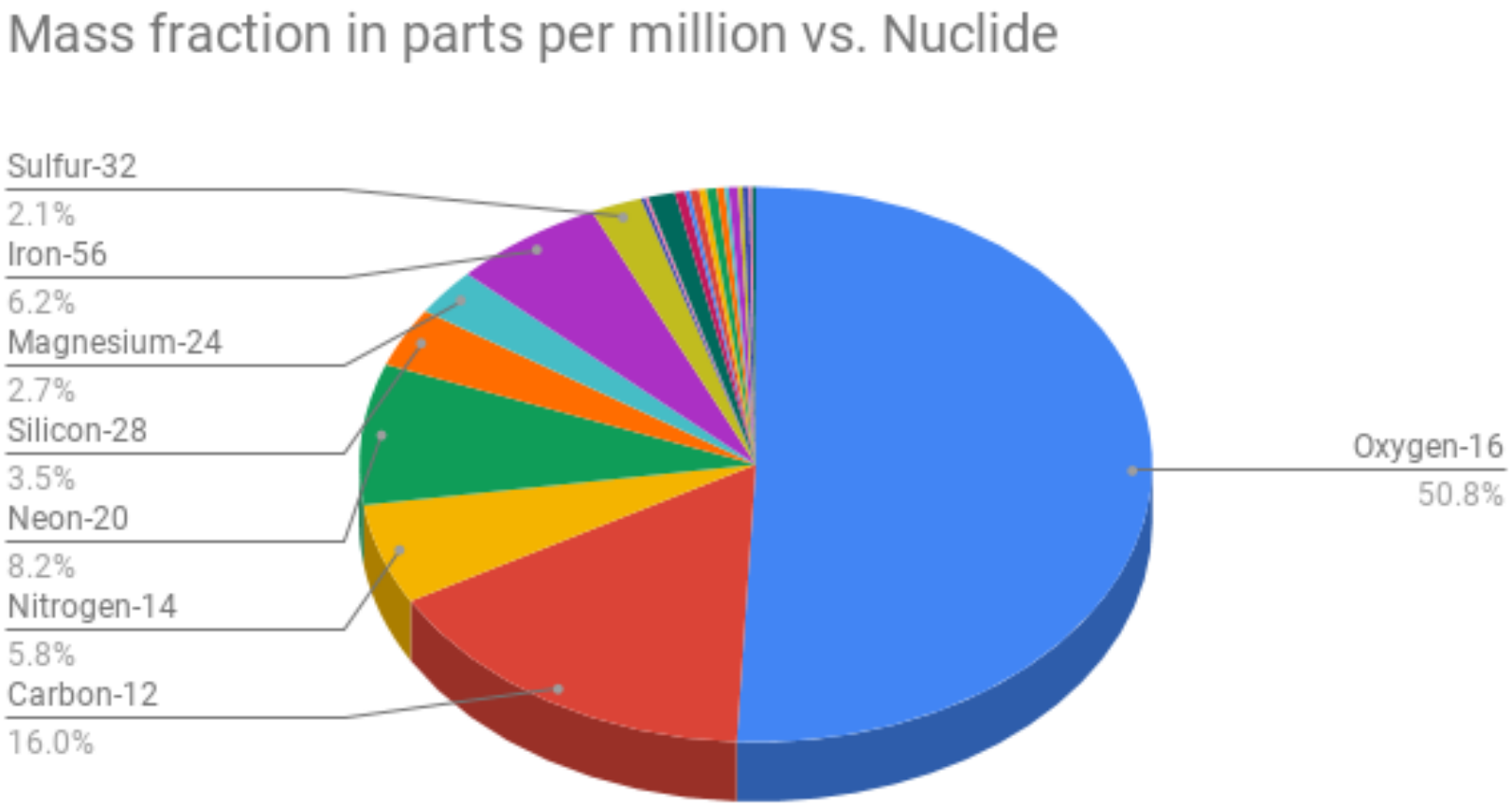

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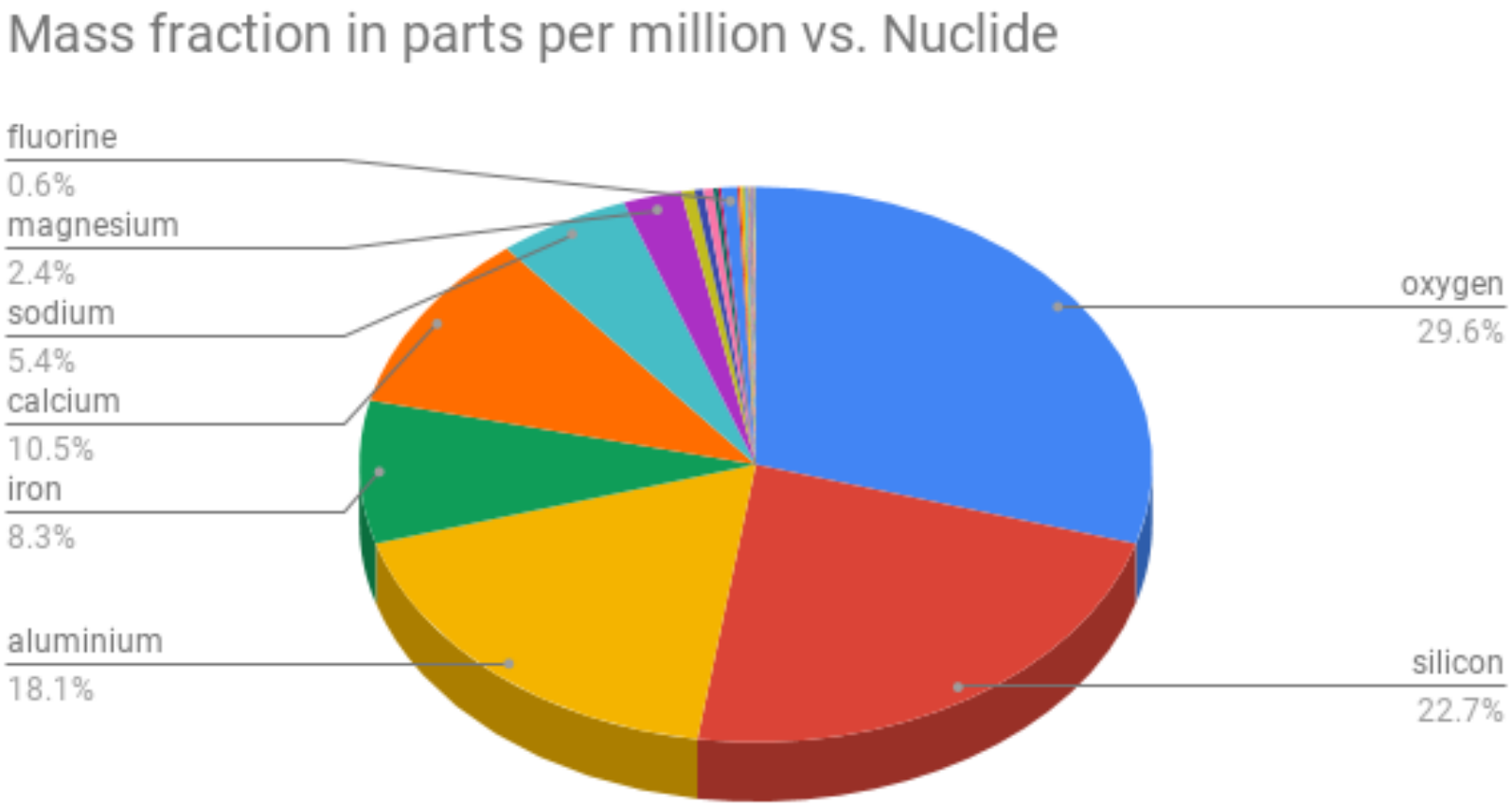

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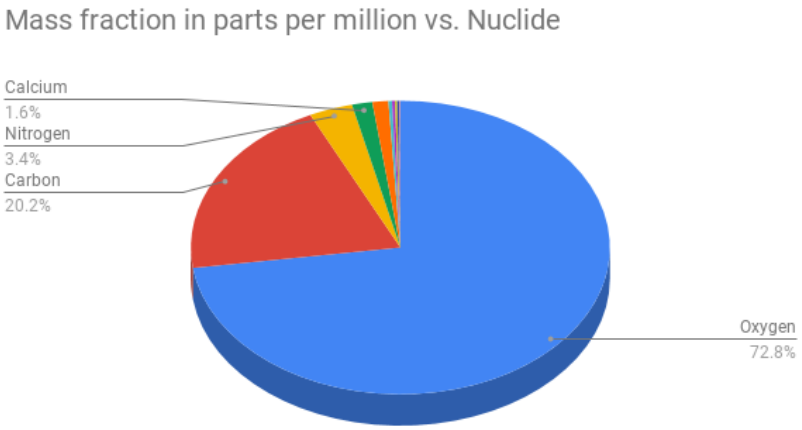
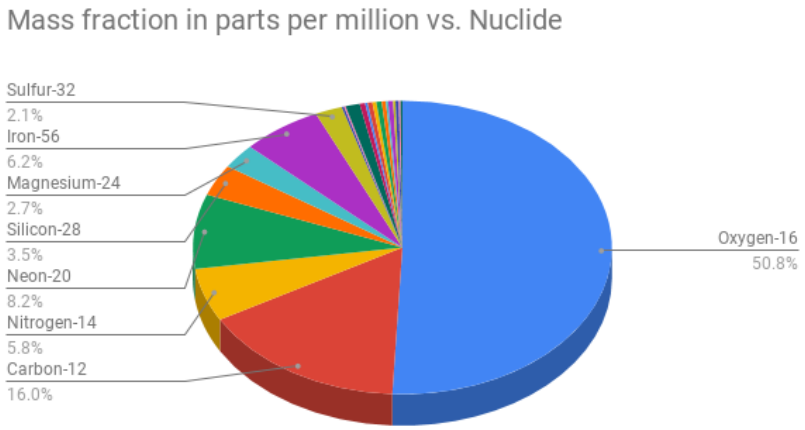
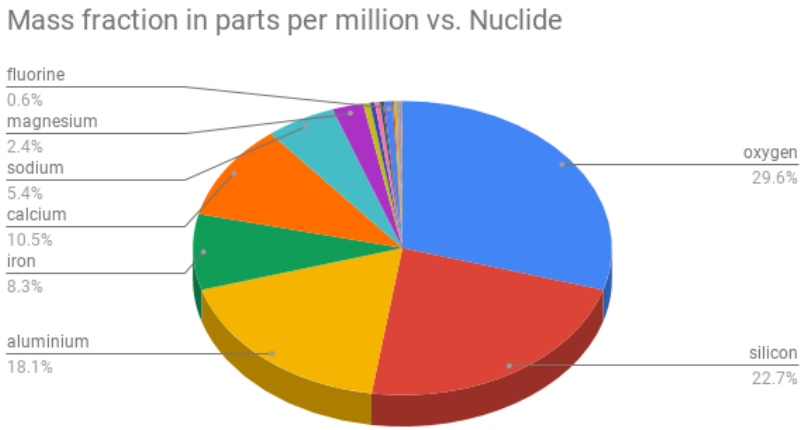
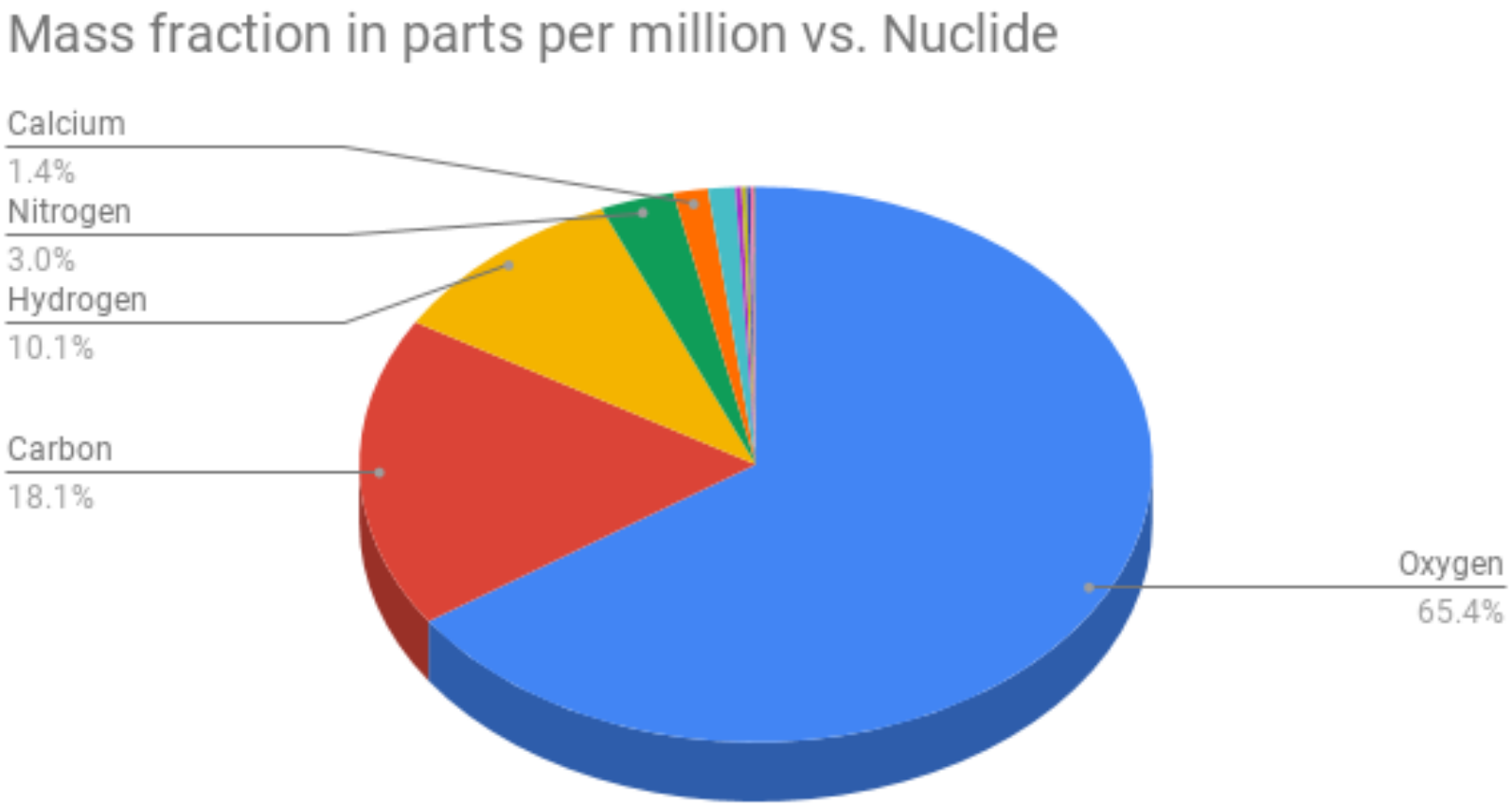


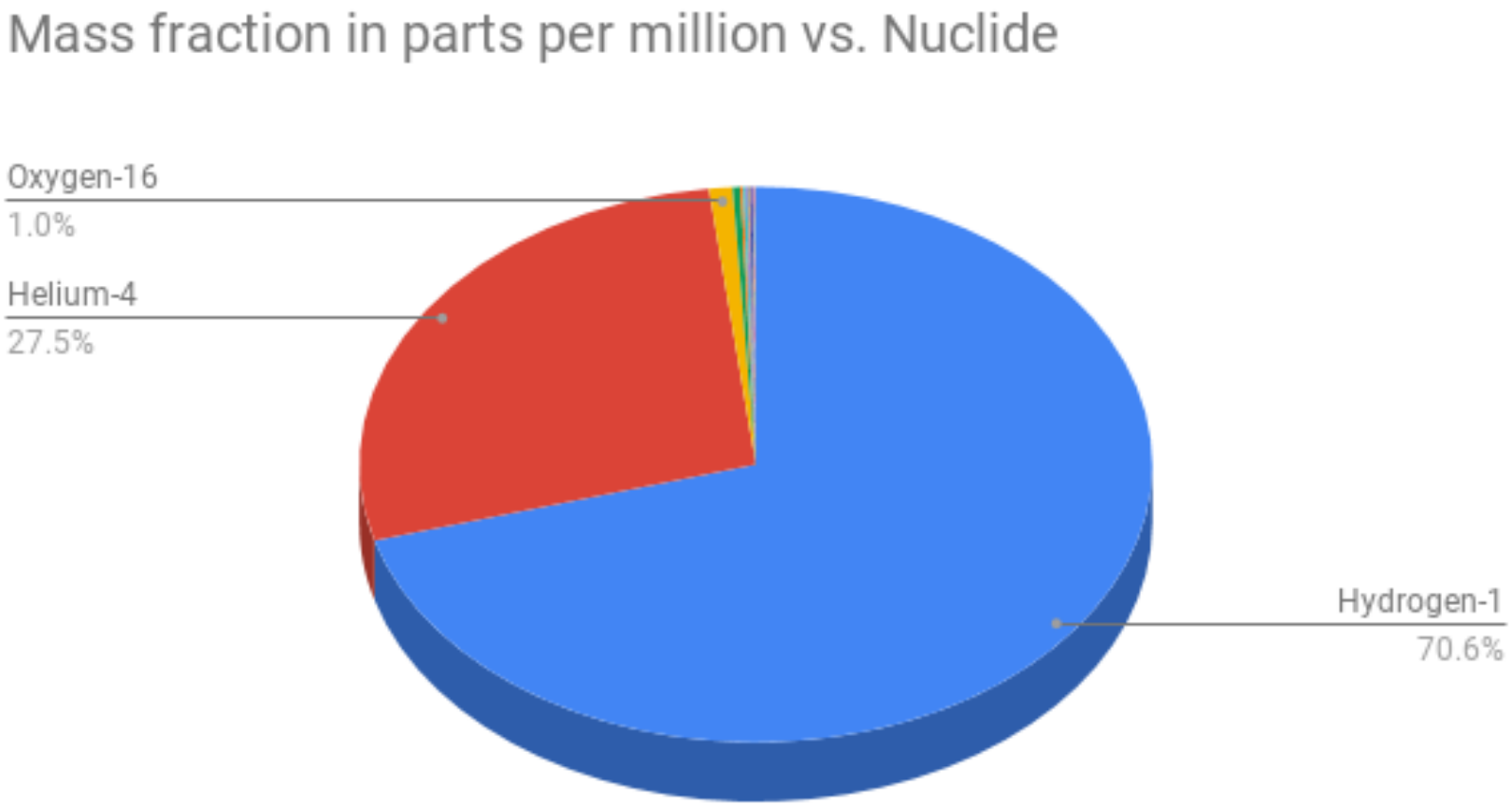




The Abundance of the Elements



The Abundance of the Elements



Stars

According to Hoyle (1946)

1. Initially the only element present in the universe is hydrogen.
2. Helium is synthesized by thermonuclear reactions taking place in "normal" stars.
3. A further process occurs that synthesizes higher elements from hydrogen and helium. The elements produced are regarded as having a distribution similar to that found on the Earth.

According to Bondi and Salpeter (1952): After all of the helium is also used up, the star again contracts gravitationally. The central temperature increases, and heavier and heavier nuclei are built up . . . This may be identified with the observed spectacle of a supernova, and all the heavy elements in the universe may owe their origin to such processes.

Stars (Hoyle 1954 - up to Nickel)

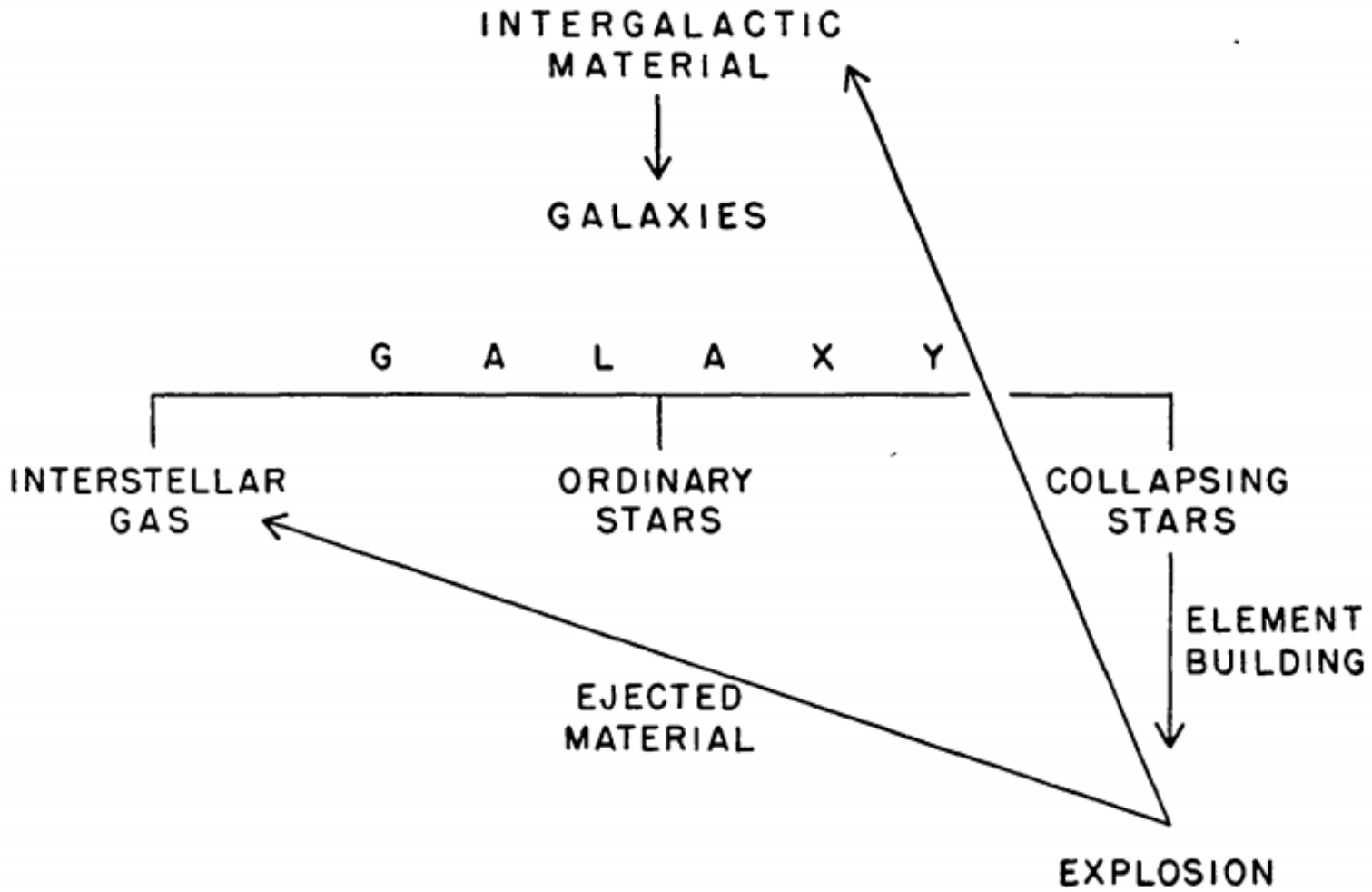
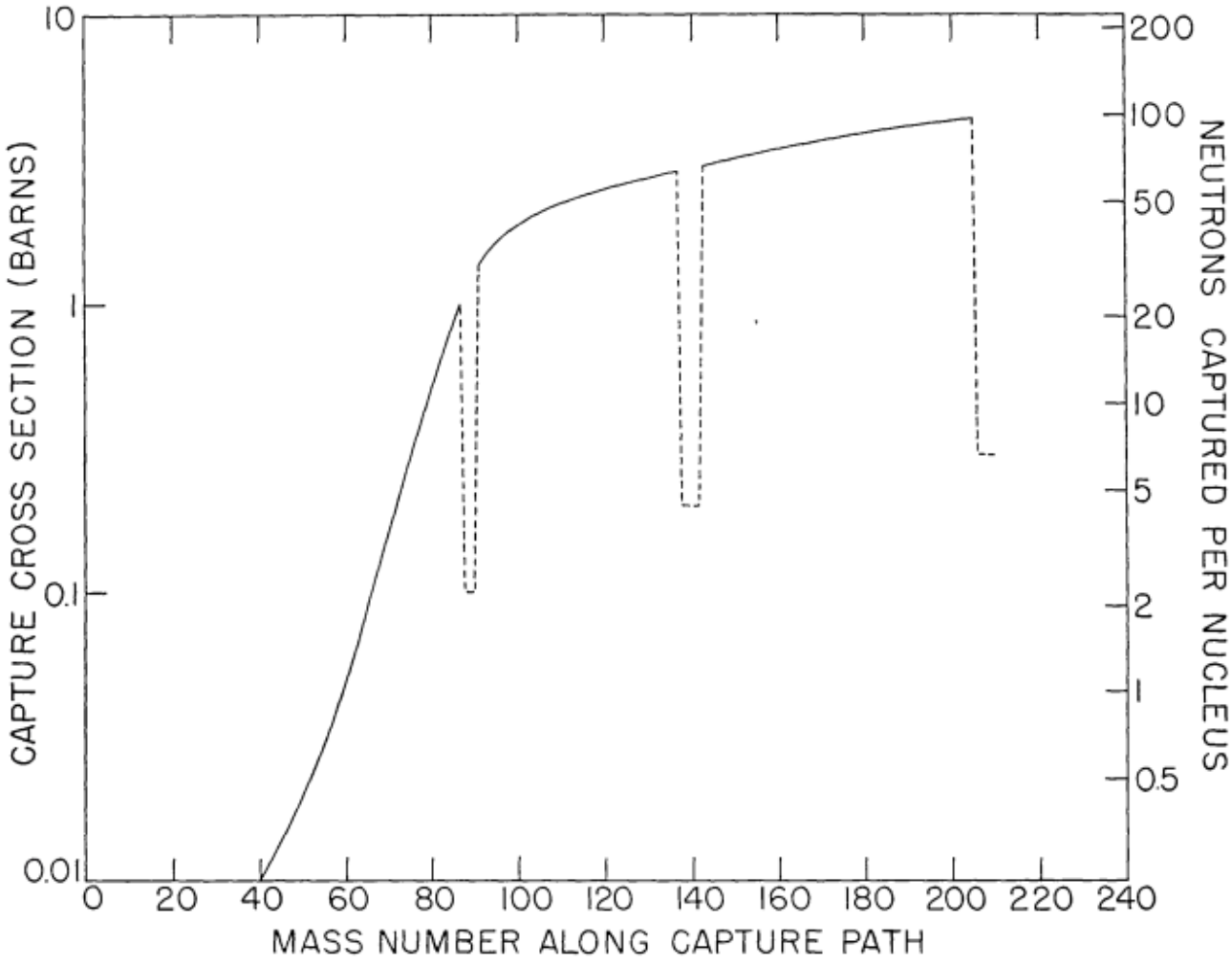


FIG. 1.—The general cosmological framework assumed for this discussion

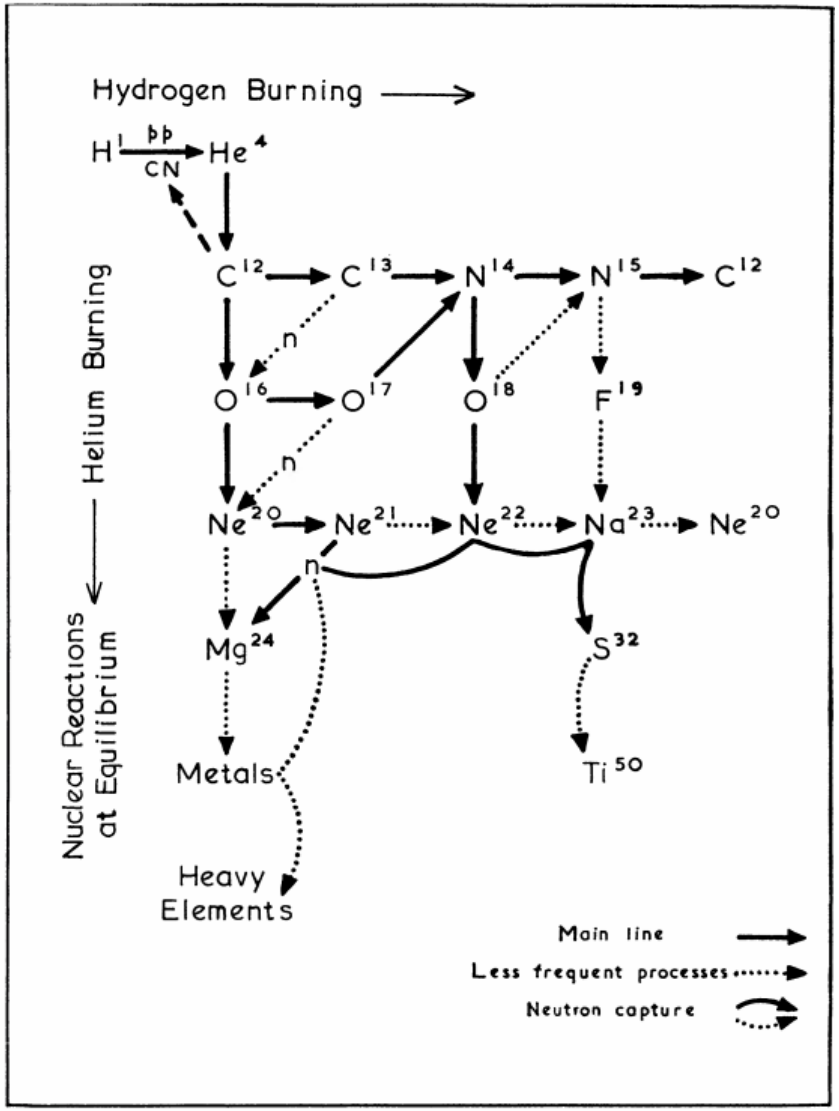
Stars (Cameron 1955)

The $C^{13}(\alpha, n)O^{16}$ reaction produces neutrons rapidly at a temperature of 10^8 K.



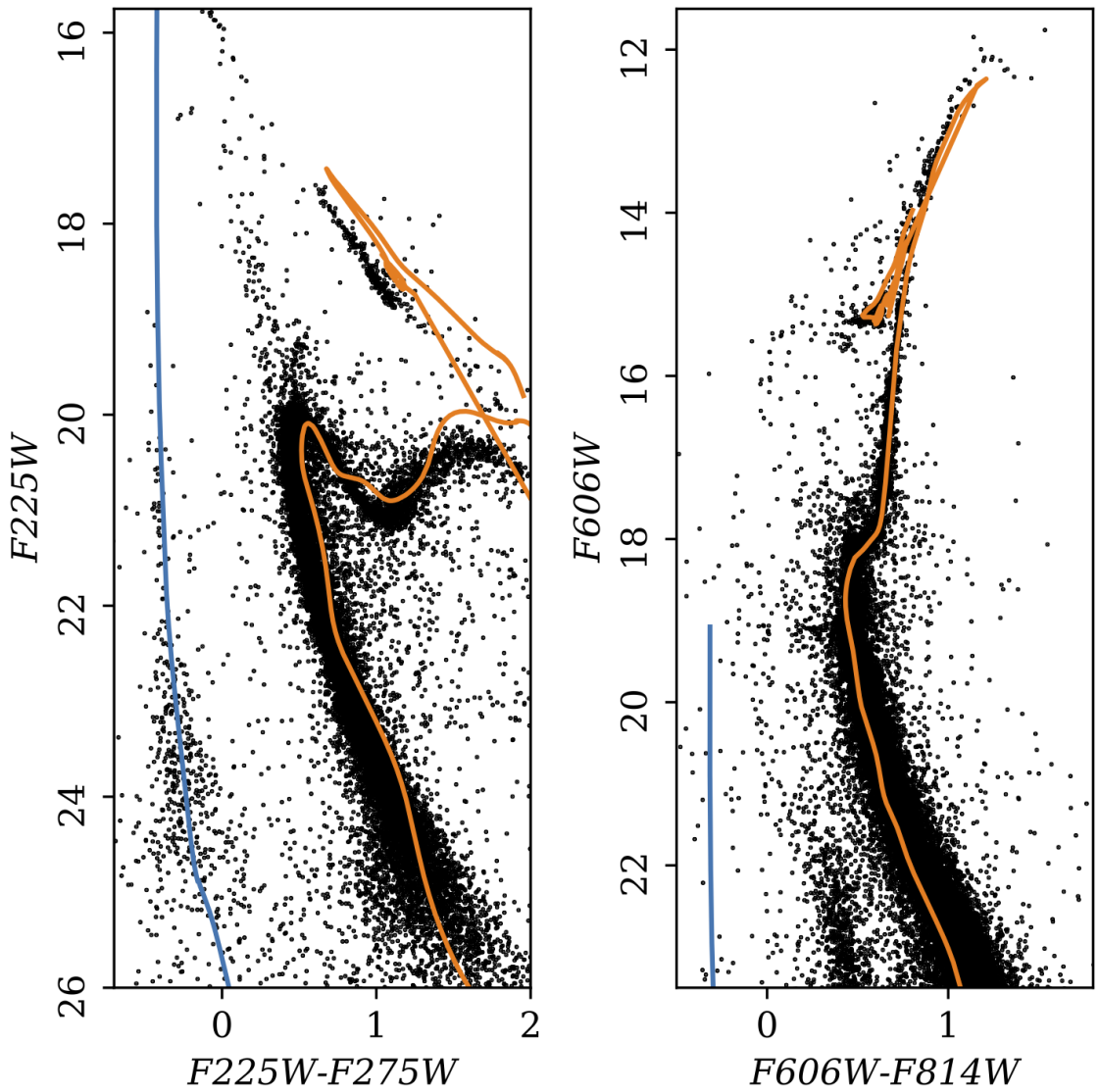
Stars (FB^2 1955a)

"Within the error due to the uncertainties in the quantities used in this estimate, it does appear, therefore, that synthesis of the heavy elements in the S-star stage alone could account for a considerable fraction of the heavy elements. A fraction of the same order would be obtained by supposing that the normal M giants were also synthesizing the heavy elements at a much slower rate."



Stars

Stars


F225W
16
18
20
22
24
26
0
1
2
F225W-F275W
F606W
12
14
16
18
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22
0
1
F606W-F814W

Stars (FB^2 1955b)

Facts about Carbon Stars:

1. Sr, Y, and Zr are overabundant by a factor of about 25.
2. La, Ce, Pr, Nd, Sm, Eu, Gd, and Dy have a mean excessive abundance ratio of the order of 600, while Ba is the only member of this group to have an apparently normal (solar) abundance.
3. Pb is probably overabundant by a factor of about 1500

Stars (FB^2 1955b)

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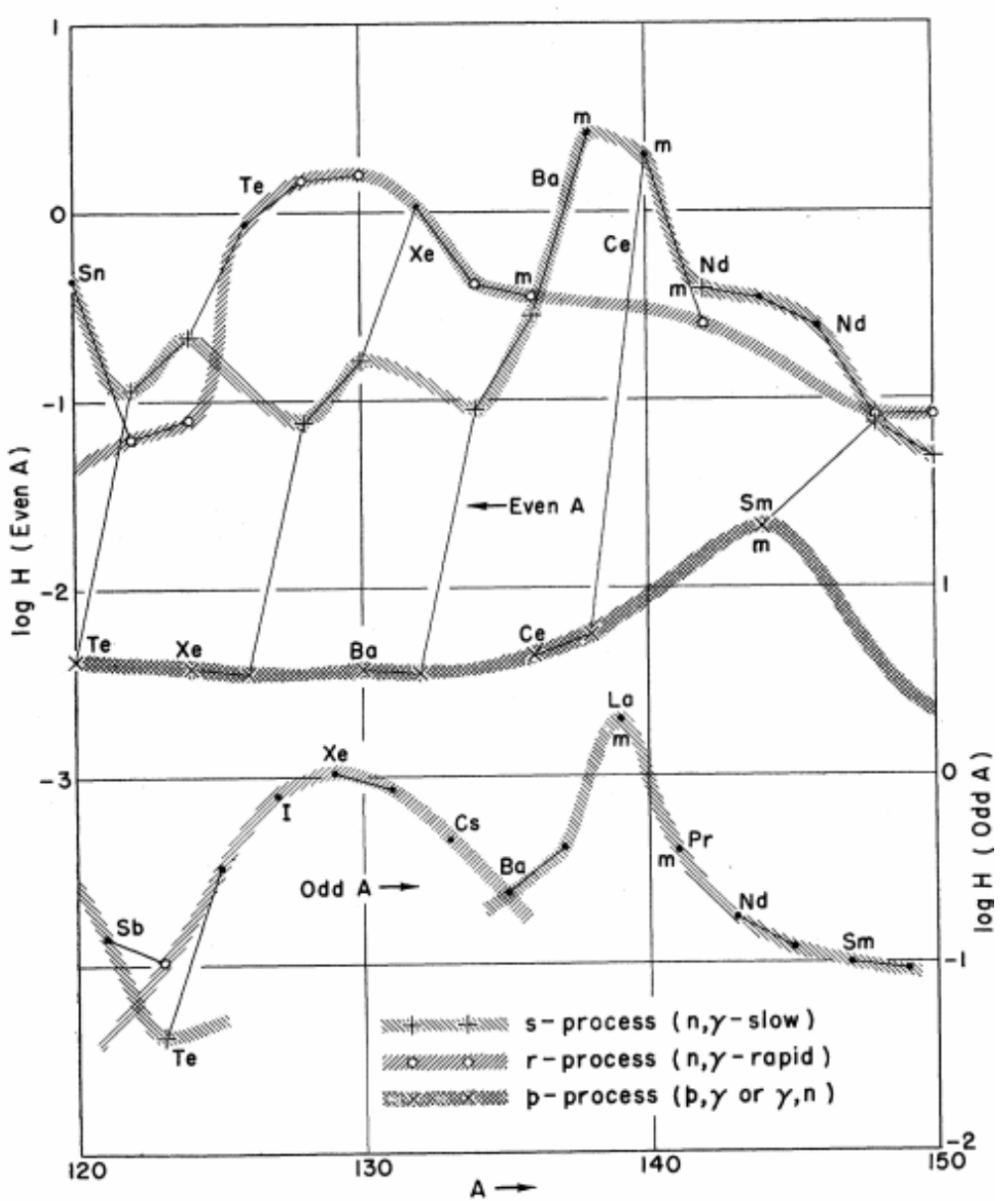
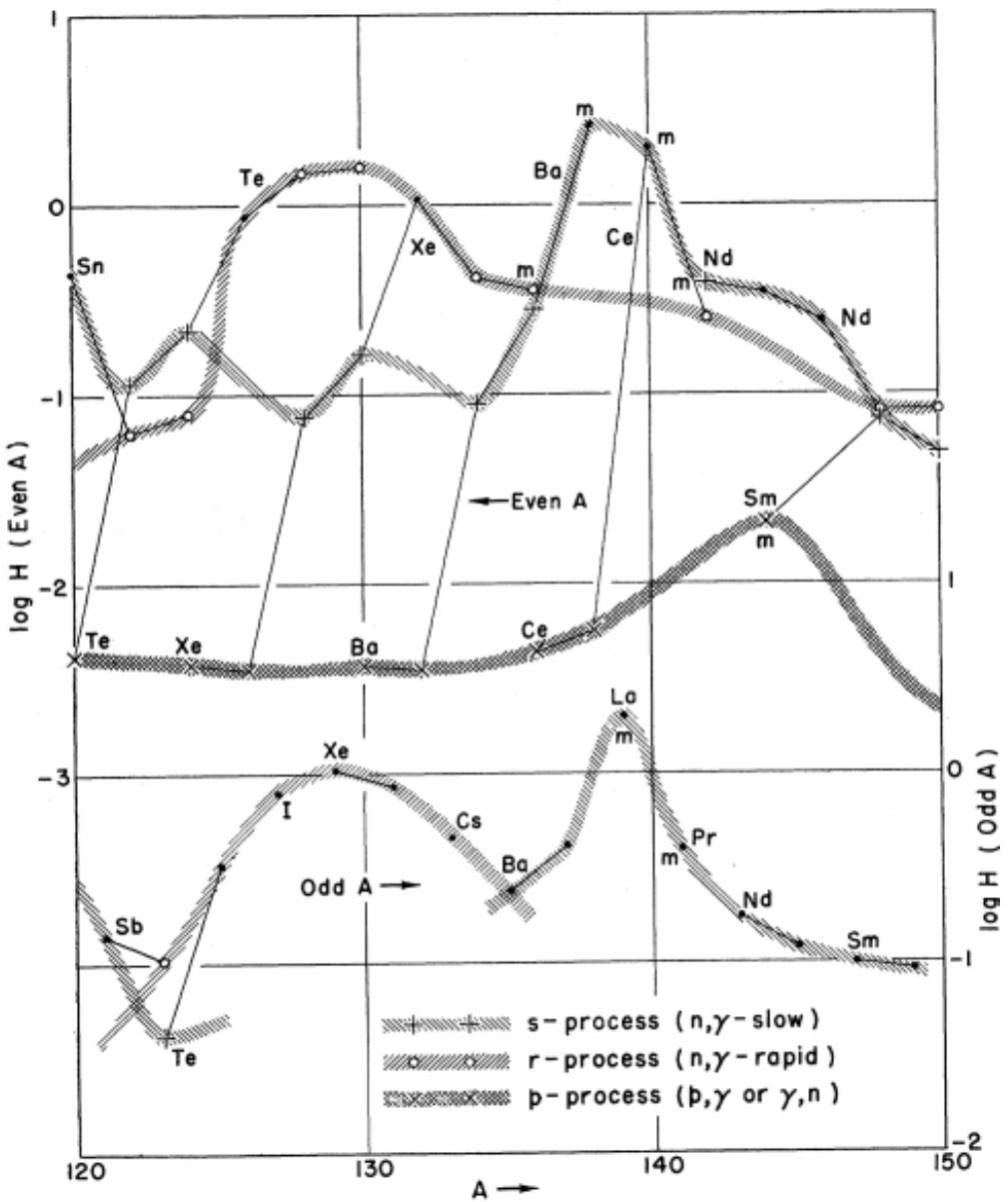
"The natural radioactive elements may be produced by collisions between metal nuclei and the stable, heavy nuclei, such as lead and bismuth."

Stars (HFB^2 1956)

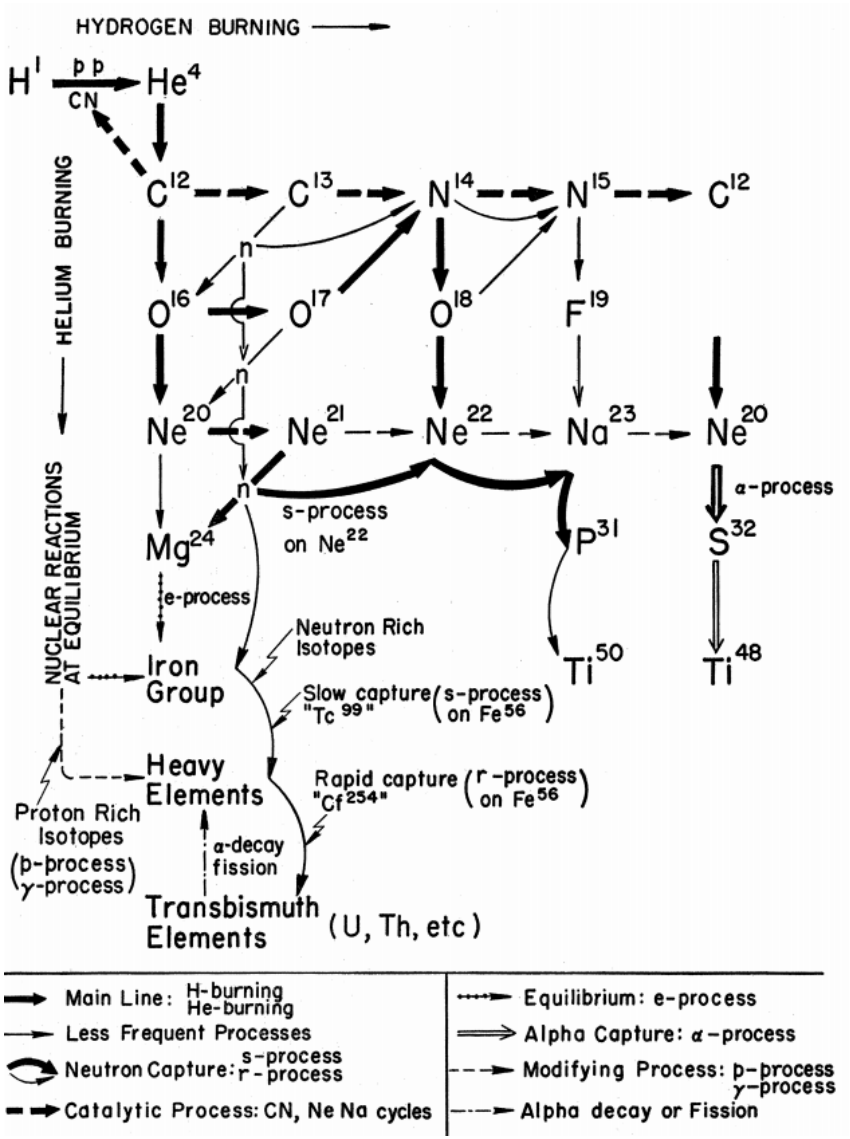


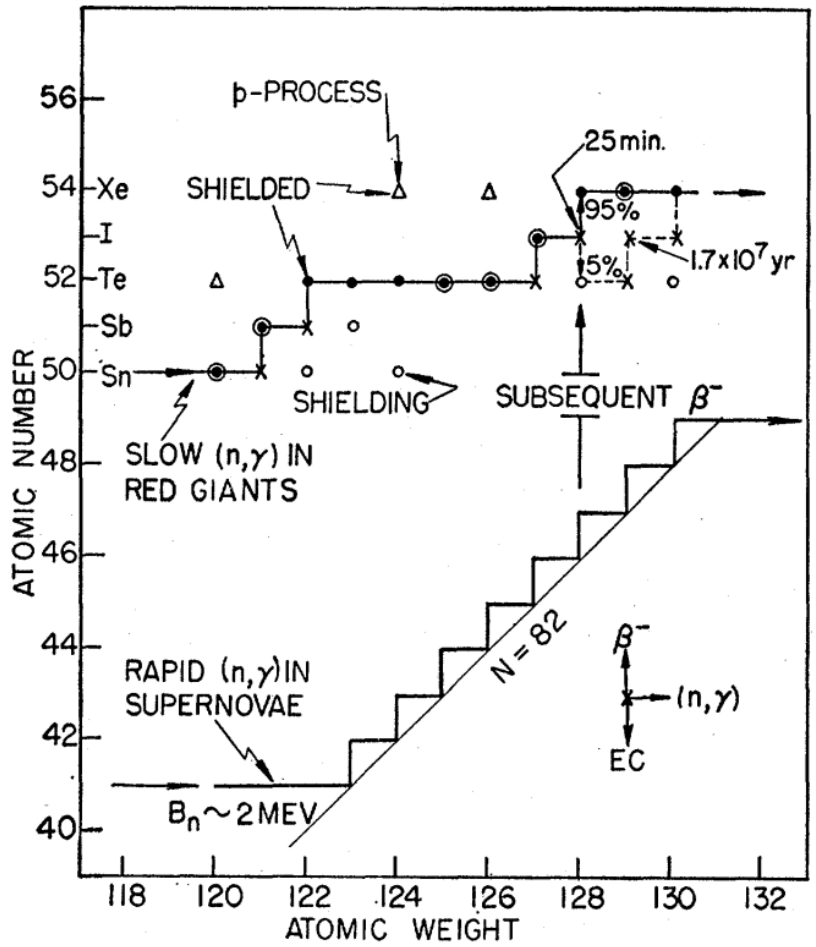
Stars (HFB^2 1956)

"The production of Cf^{254} in the thermonuclear test at Bikini in November 1952 demonstrates that rapid neutron capture can surmount spontaneous radioactivity"



Stars (B^2FH 1957)





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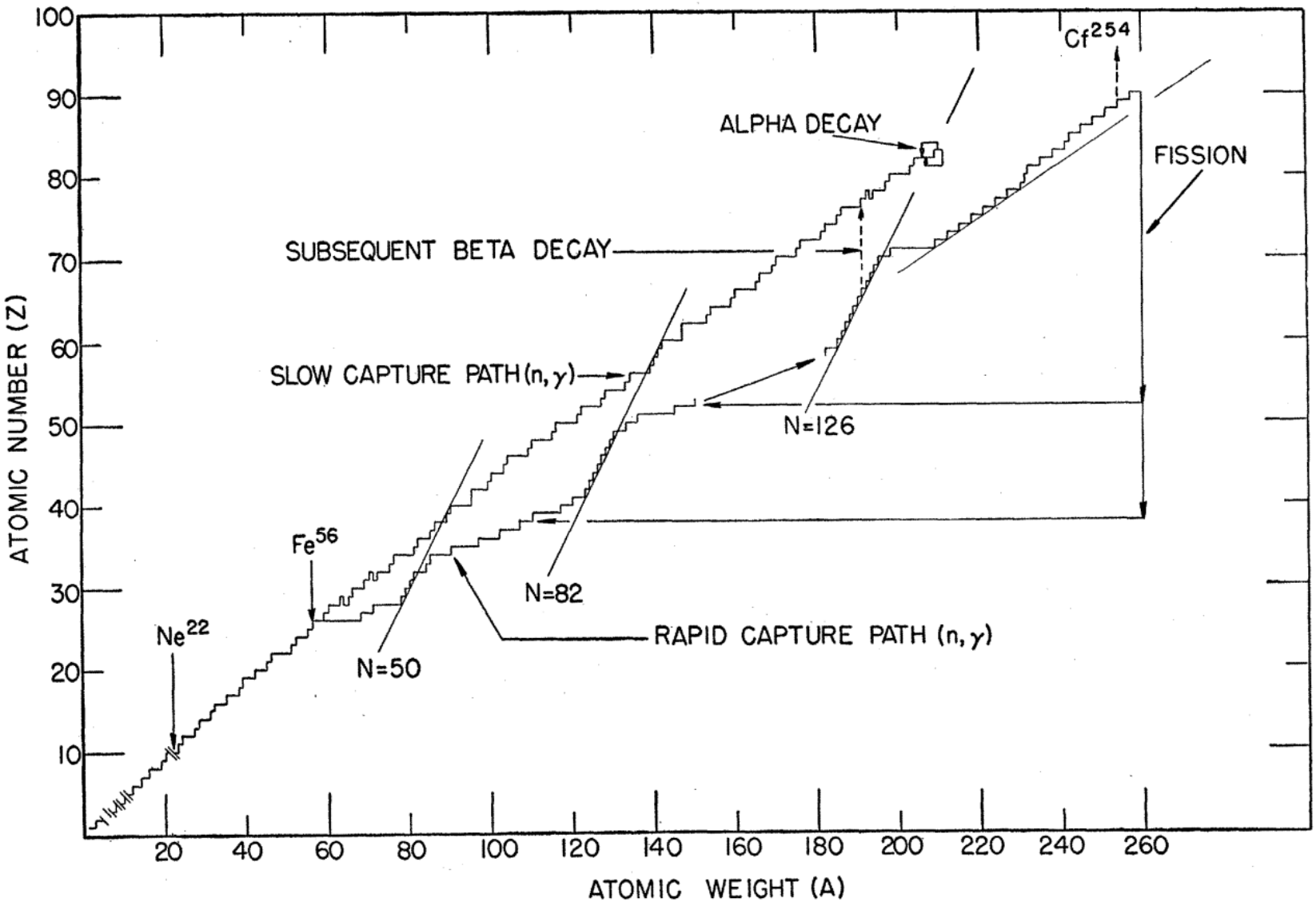

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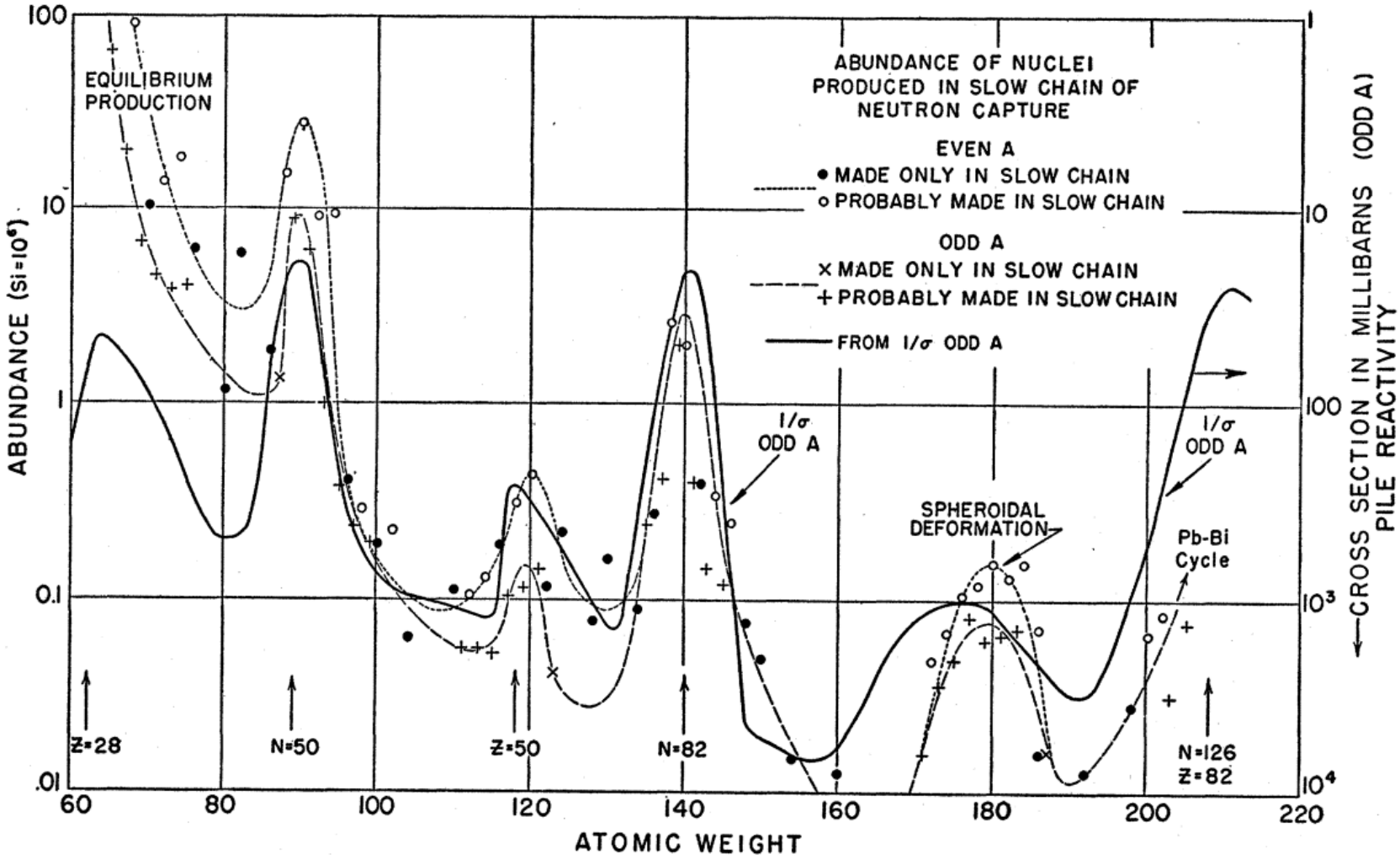

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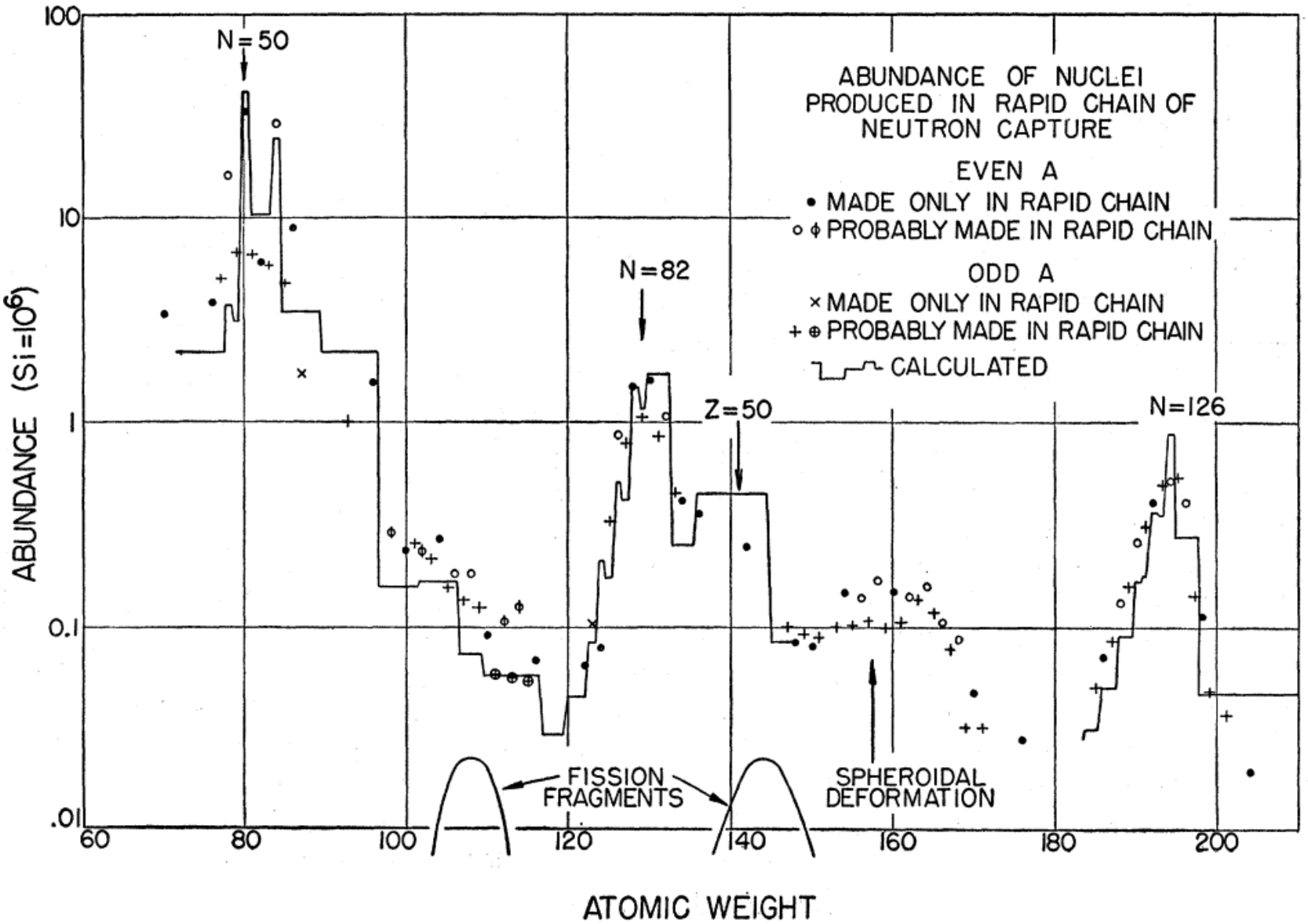
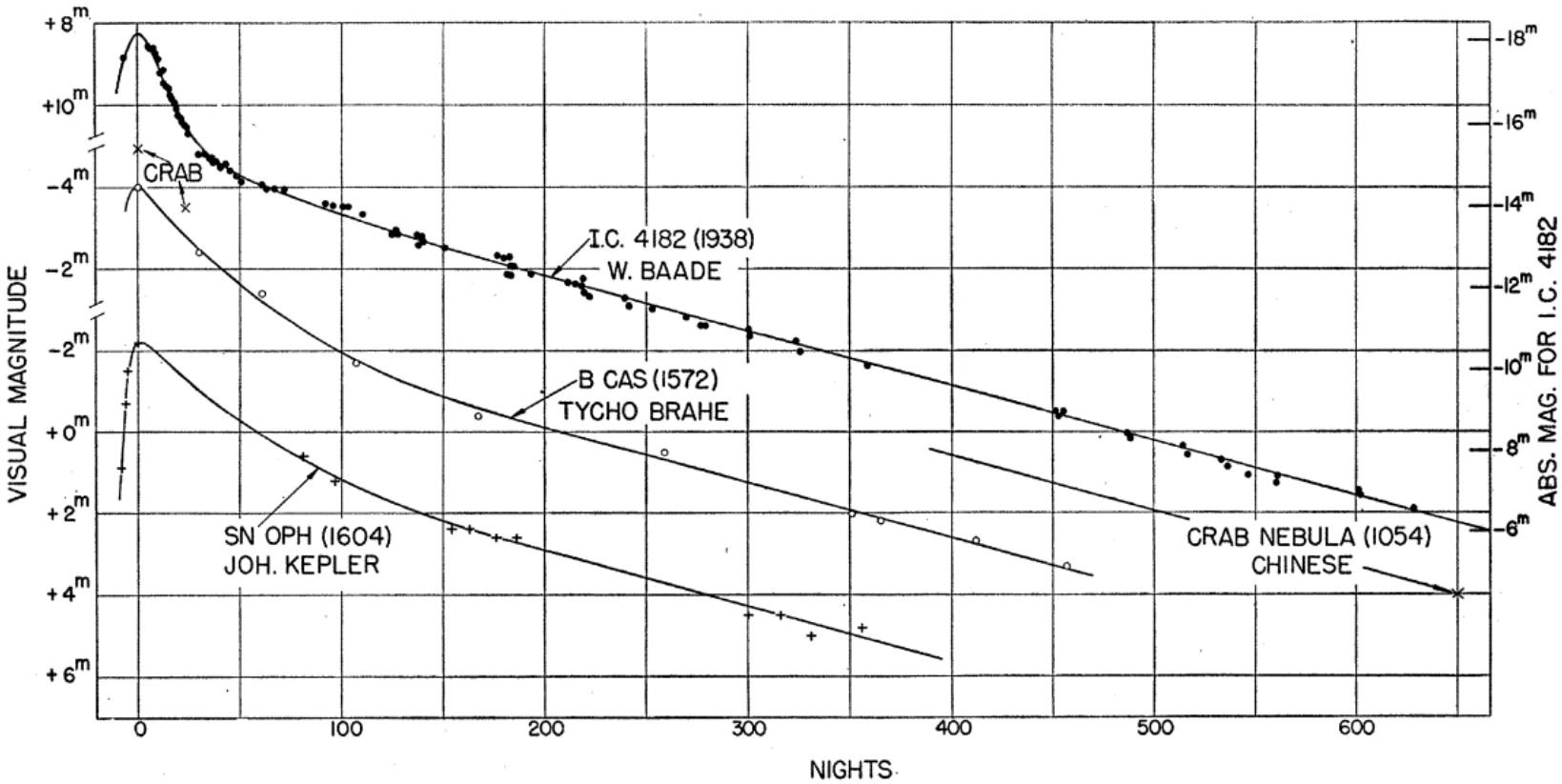
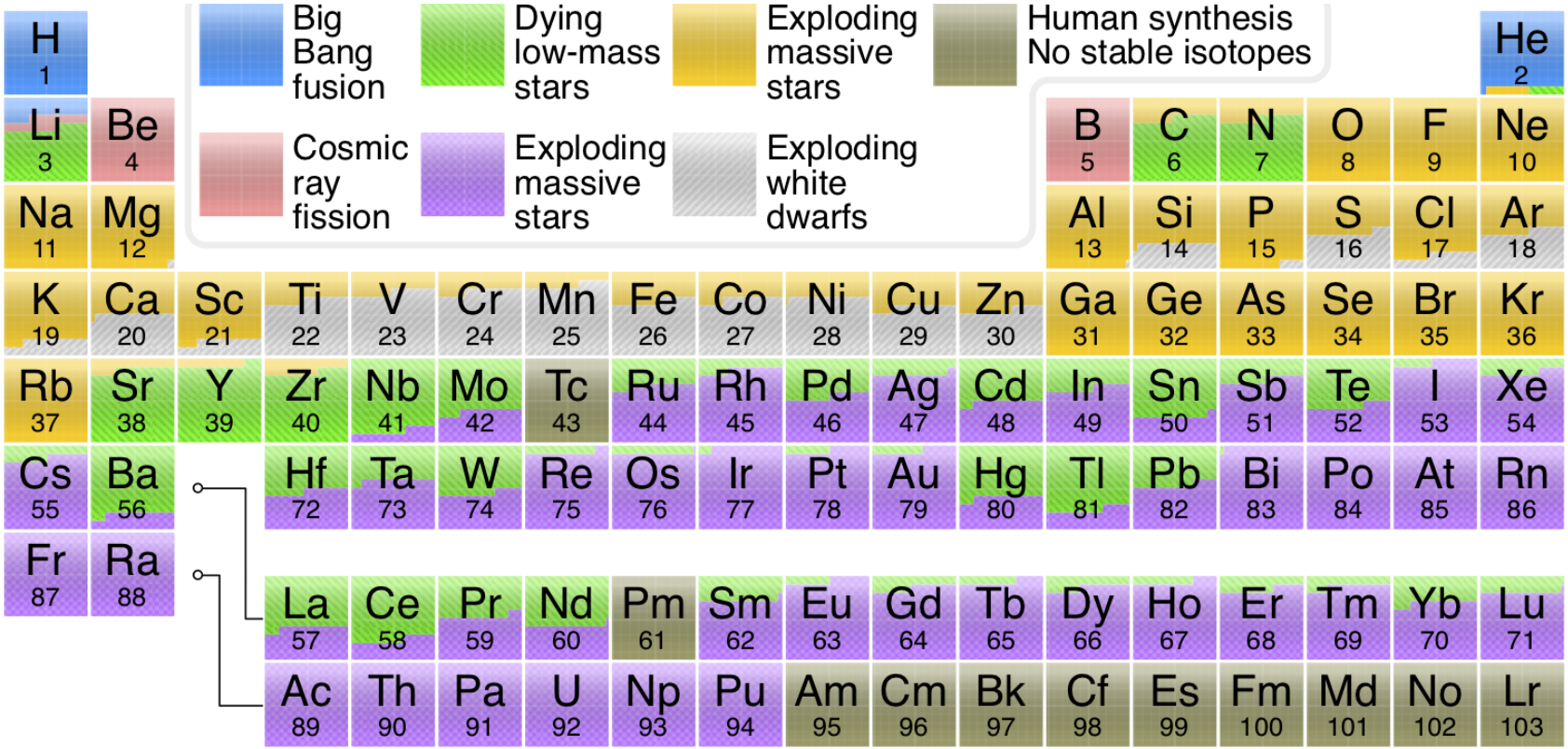


Stars (B^2FH 1957)

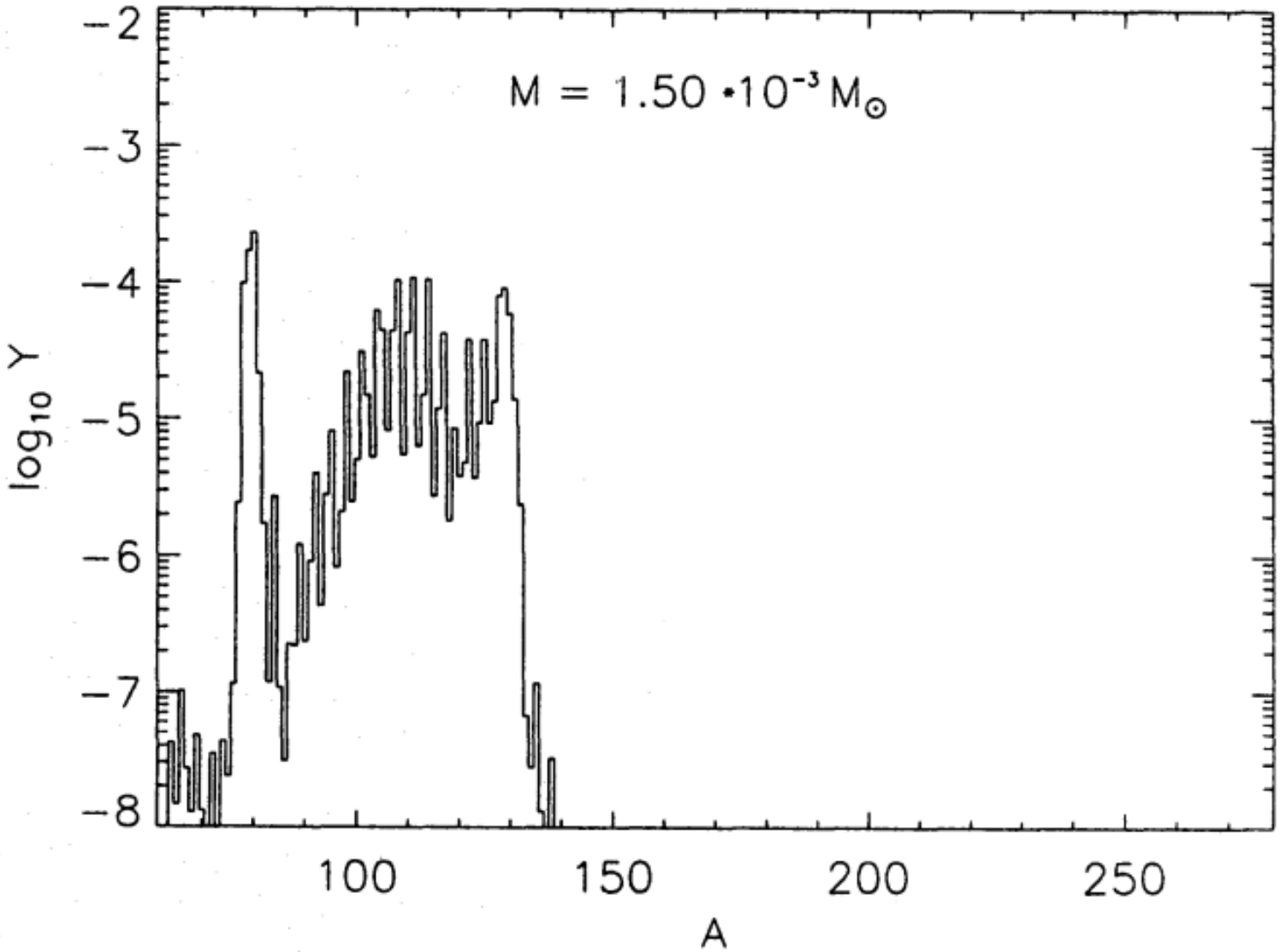


Nucleosynthesis



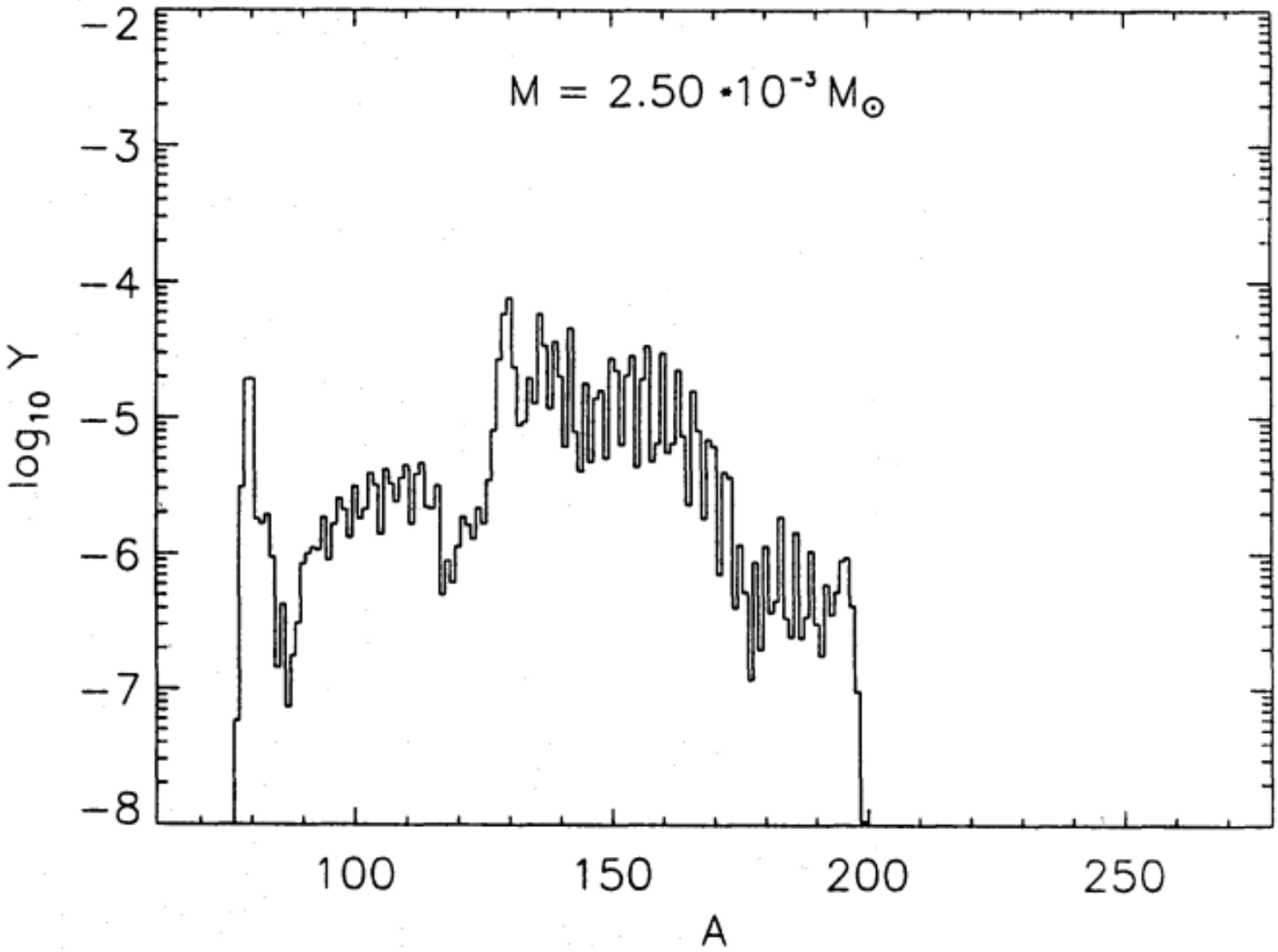
Jennifer Johnson

$r-$process in Core-Collapse SN to the limit



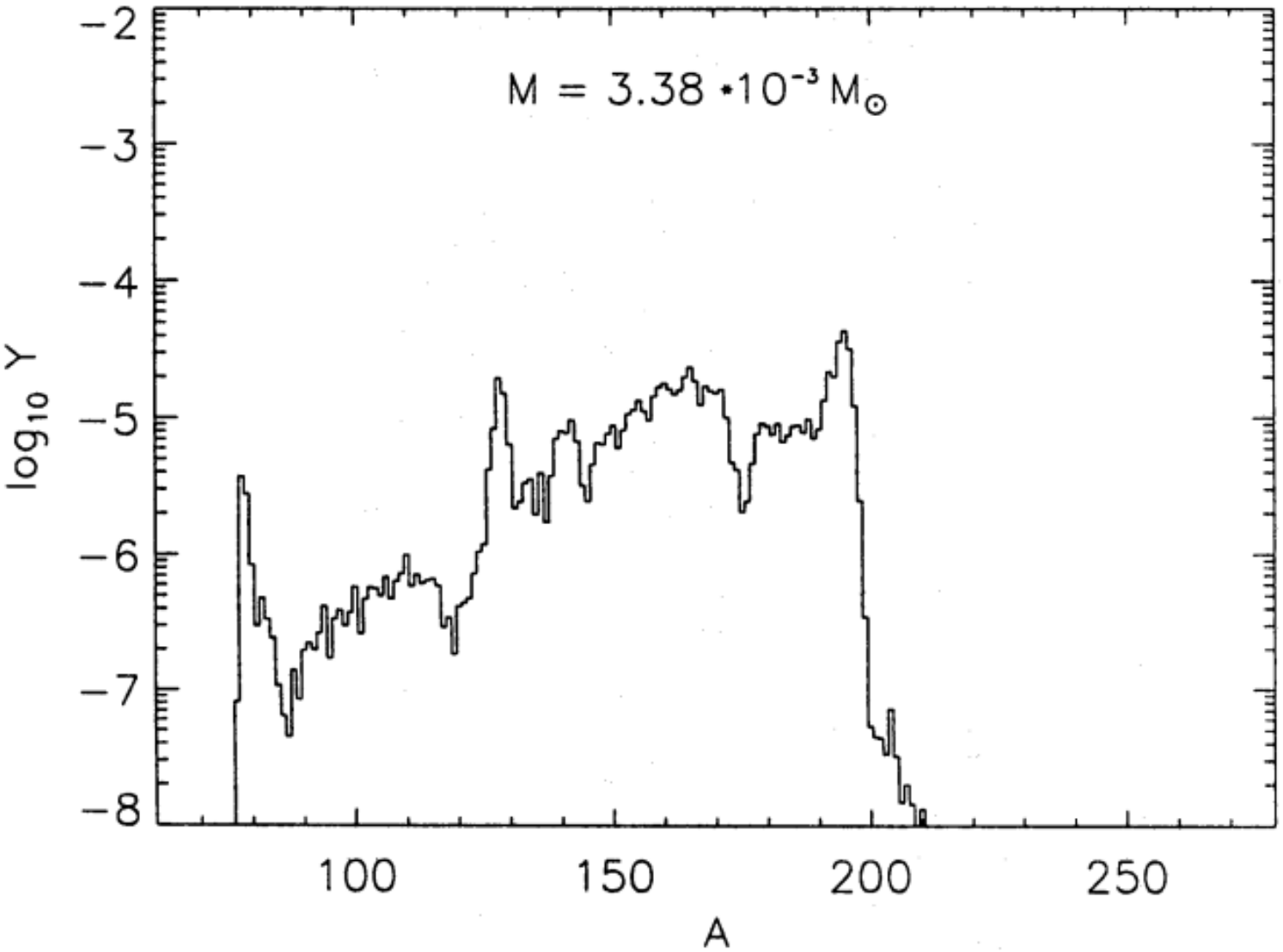
Takahashi, Witti & Janka 1994, $Y_n / Y_{\mathrm{seed}} = 19$

$r-$process in Core-Collapse SN to the limit



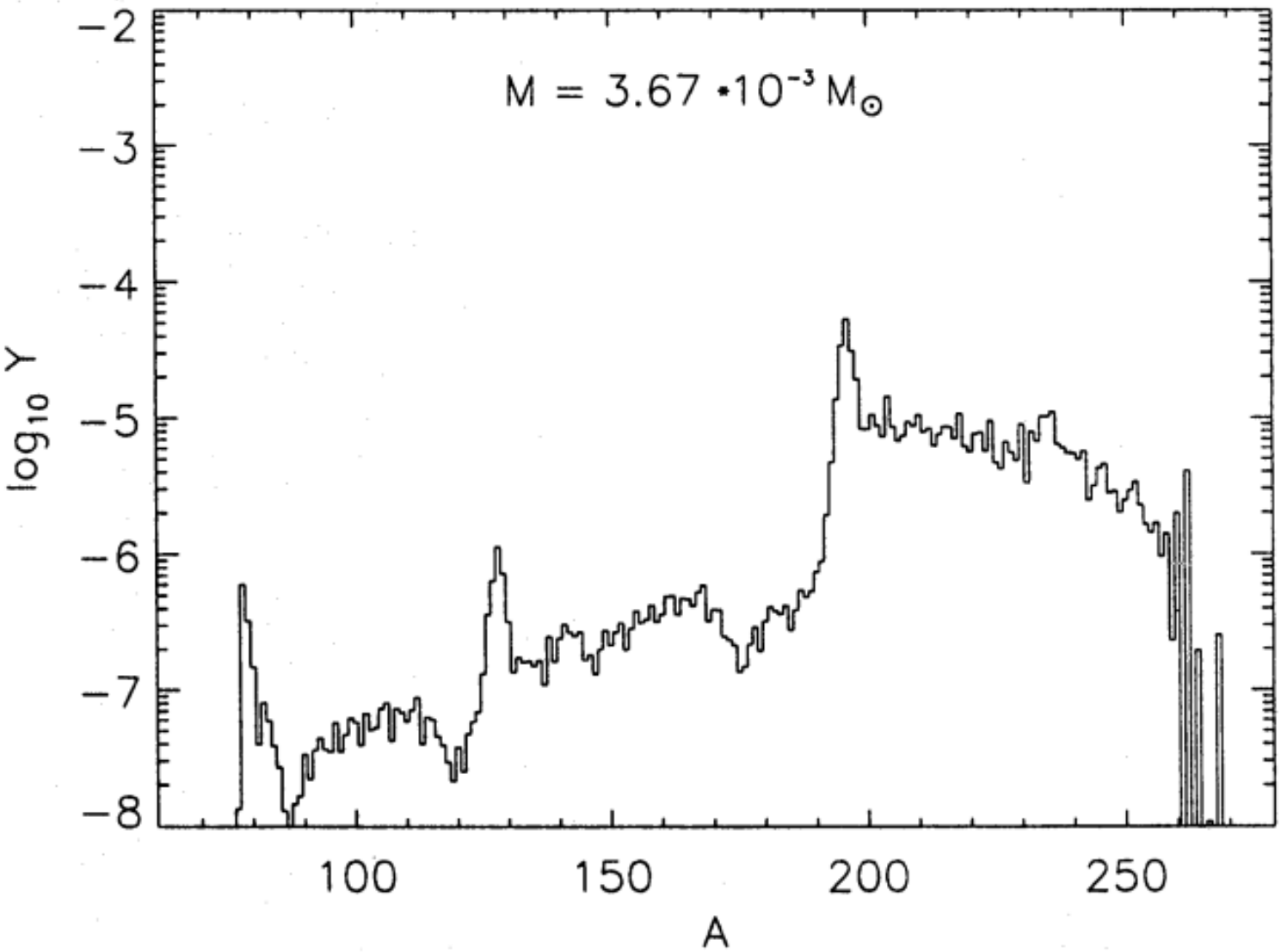
Takahashi, Witti & Janka 1994, $Y_n / Y_{\mathrm{seed}} = 51$

$r-$process in Core-Collapse SN to the limit



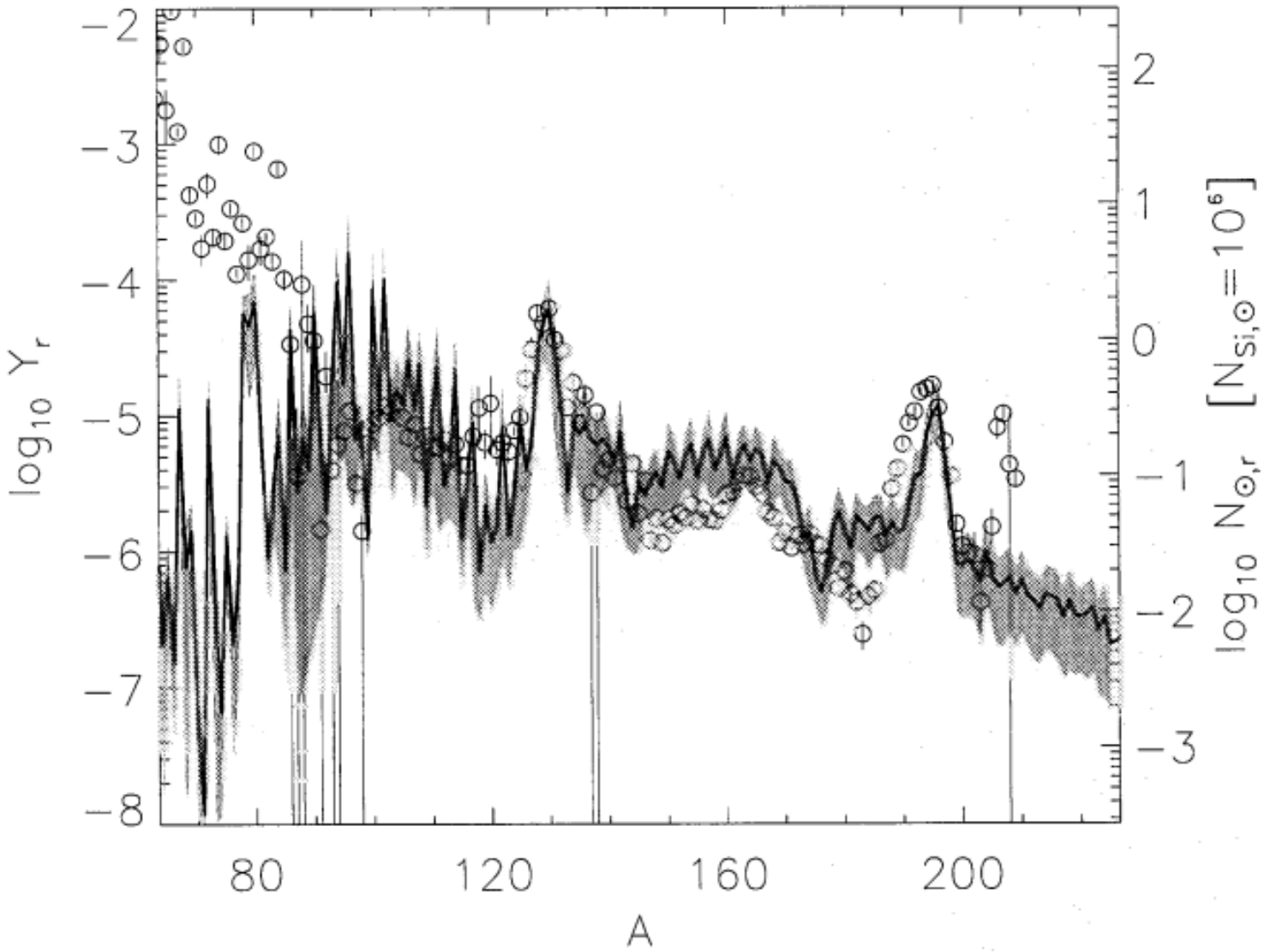
Takahashi, Witti & Janka 1994, $Y_n / Y_{\mathrm{seed}} = 75$

$r-$process in Core-Collapse SN to the limit



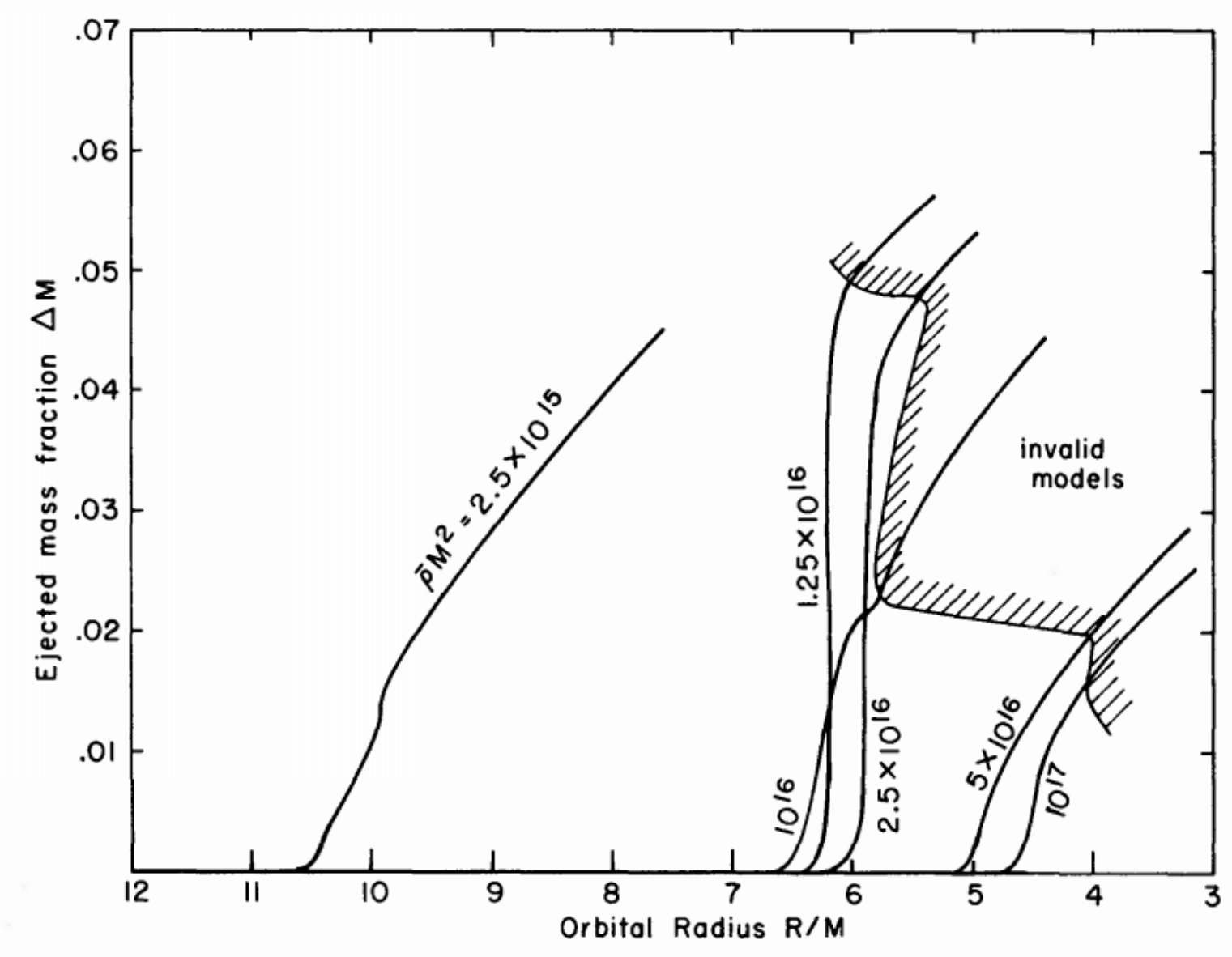
Takahashi, Witti & Janka 1994, $Y_n / Y_{\mathrm{seed}} = 125$

$r-$process in Core-Collapse SN to the limit



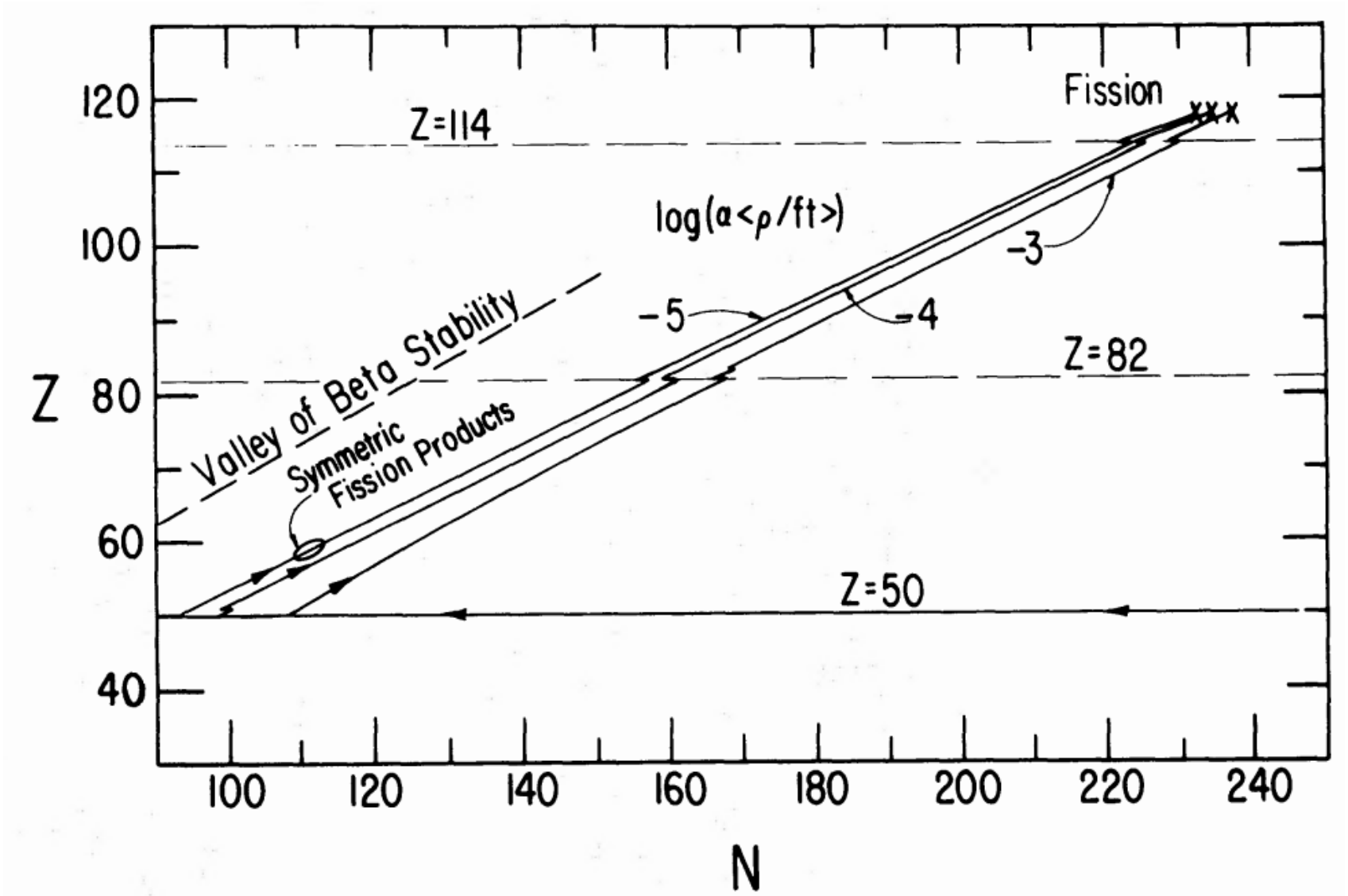
Takahashi, Witti & Janka 1994

Another $r-$process



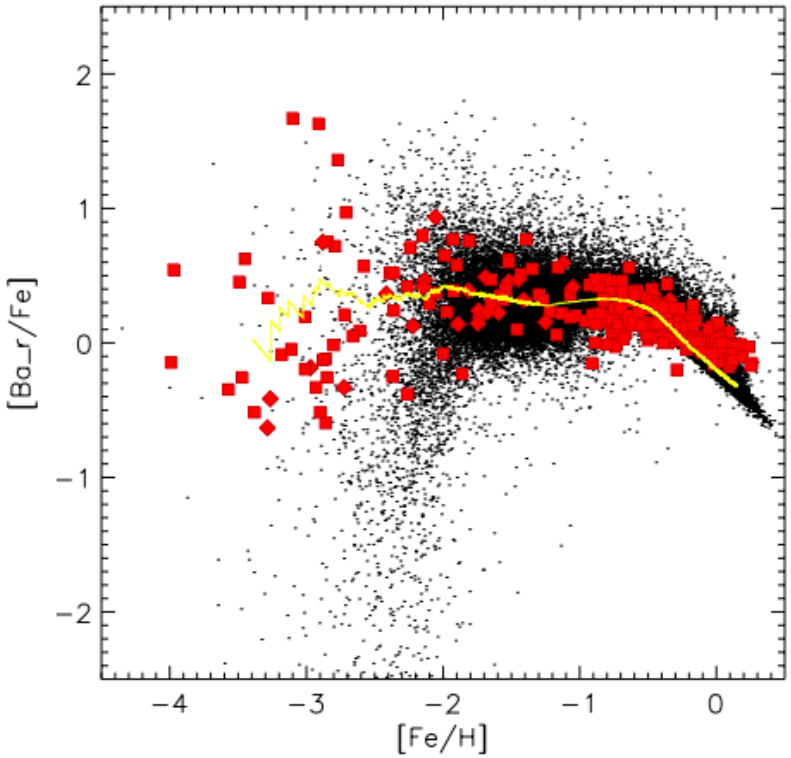
Lattimer & Schramm 1976

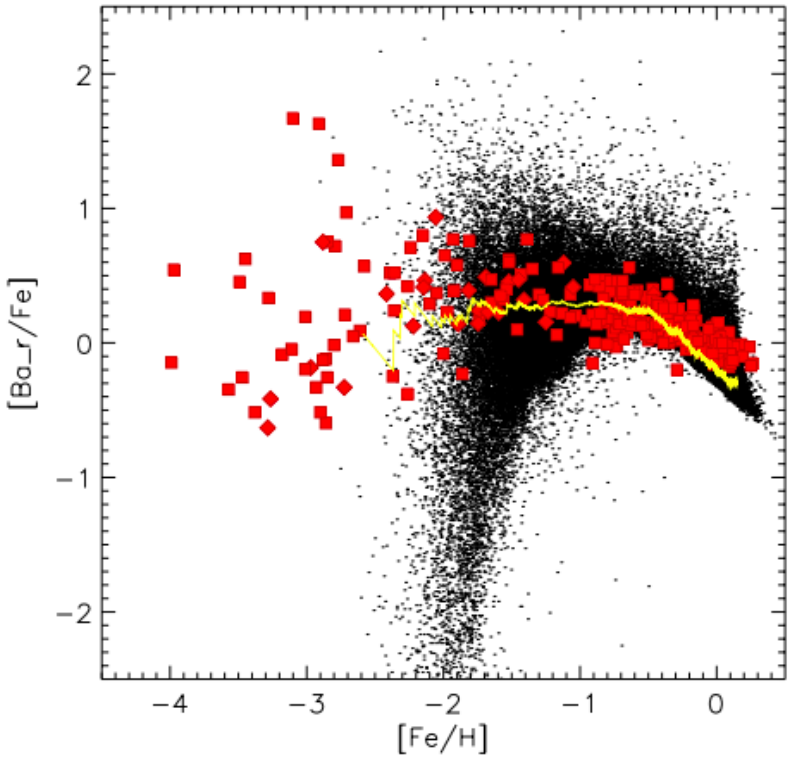
Another $r-$process



Lattimer et al. 1977

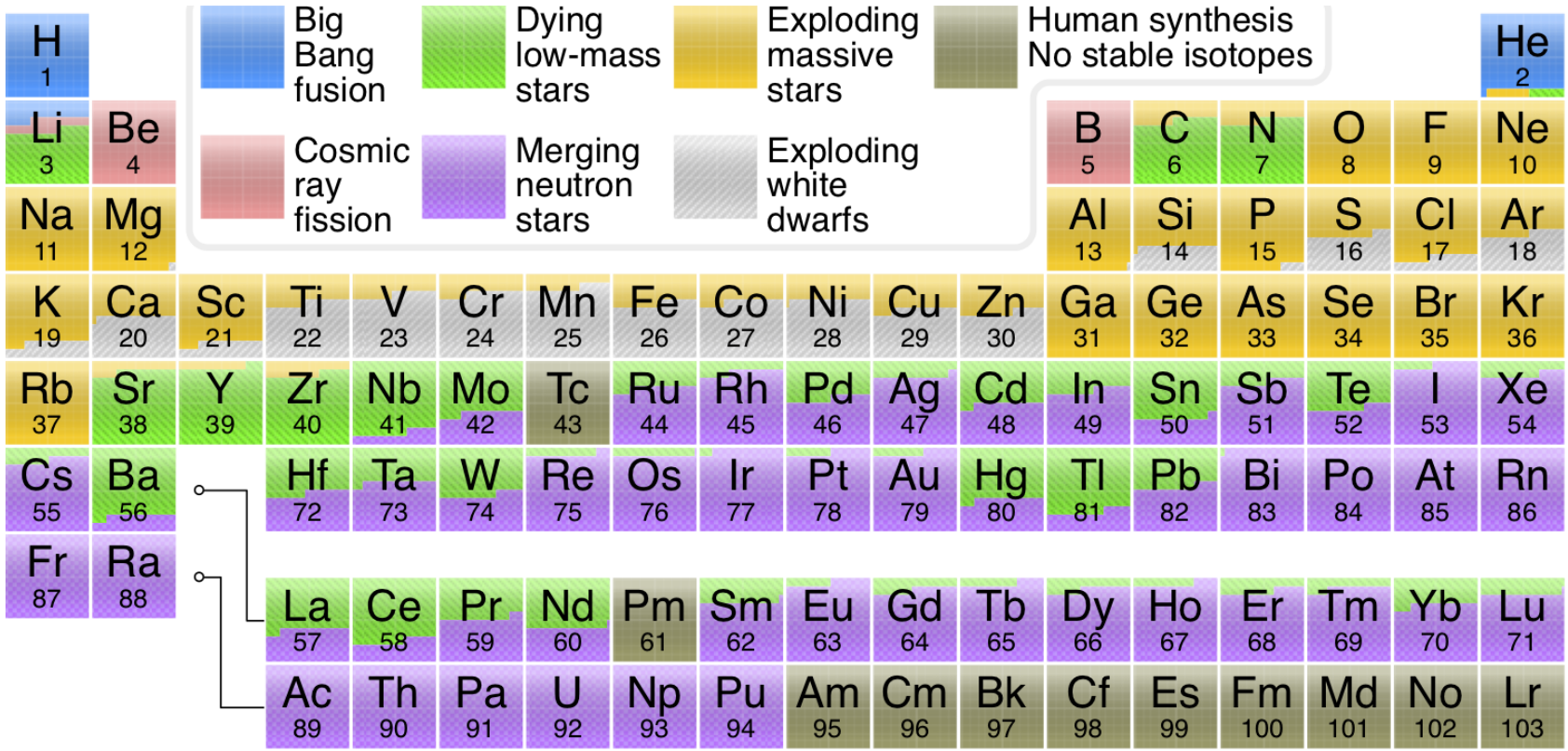
A Modern Picture





Argast et al. 2003; 200 Myr^{-1}, 20 Myr^{-1}

Nucleosynthesis



Jennifer Johnson

Full Circle

- Alpher, Bethe and Gamov (1948) argued that the nuclei built up through neutron capture in the expanding "overheated neutral nuclear fluid" after the Big Bang.
- Most of the $r-$process occurs through neutron capture in the expanding "cold neutral nuclear fluid" in neutron-star collisions.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