ON THE BULK YIELDS OF NUCLEOSYNTHESIS FROM MASSIVE STARS

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Preliminary estimates are made of the absolute yields of abundant nuclei synthesized in observed stars. The compositions of helium stars of mass $3 \leq M\alpha / M_\odot \leq 64$ are presented, taken at the instant of instability. These stars of mass $M\alpha$ are identified with stars of main sequence mass M. The amount of synthesized matter for each mass $M \geq 10\ M_\odot$ is estimated (Table 1). Using a variety of choices for the initial mass function (IMF) the yield per stellar generation is calculated. For standard choices of the IMF the absolute and relative yields of ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg, the Si to Ca group and the iron group agree with solar system values, to the accuracy of the calculations.

Galactic evolutionary models must be consistent with the paucity of metal-poor low mass stars; there are several ways to accomplish this. The identification of ^{244}Pu, ^{129}I and ^{26}Al as present in the early solar system demands that nucleosynthesis be an ongoing process in the galaxy. Many currently interesting models which can satisfy these two constraints predict that the abundance of nucleus i approaches

$$X_i \rightarrow q_i/(1-f),$$

where f is the fraction of matter returned to the interstellar medium by stars of mass $M \gtrsim 1\ M_\odot$ ($f = 0.15$). This is true of infall models, inhomogeneous models or metal-enhanced star formation models. It is not true for initial burst models with a changing IMF or models in which metal rich gas flows in from a massive halo or out from the galactic nucleus.

The numerical values of the dimensionless yields, $q_i / (1-f)$, for a generation of stars are given in Table 2 for a variety of values of α, the IMF power law above $M = 10\ M_\odot$. The net yeild of heavy elements (the sum of C through Fe entries) is given as z in the last column. For comparison the fractions by mass of these nuclei in the

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solar system is also given in the row labled "solar". The corresponding production matrix q_i for a generation of stars, a quantity of importance to a wider class of models of galactic evolution, can be obtained by multiplying the entries in Table 2 by (1-f) = 0.85

Note that the ^{4}He production is adequate to explain only about 10% of the solar system value. Mixing, mass loss and binary interaction might conspire to increase the He yield, but most of the ^{4}He must be formed some other way, probably cosmologically. The estimated value of the yields varies by a factor of ten as α is changed from 4/3 to 10/3; this is the major effect of varying α. Except for He the general shape of the abundance curve is similar to that for the solar system. The dip at Ne - Mg is not so pronounced in the theoretical curve. Explosive reprocessing might remove some of this difference, as might use of better reaction rates. An interesting aspect of Table 2 is the lack of pronounced variation of relative abundances with the slope α of the IMF.

In a second approach, using standard estimates (Ostriker, Richstone and Thuan) for the current rate of stellar death, the present rate of nucleosynthesis in the solar neighborhood is found to be about 10% of the average rate over galactic history. This result is consistent with many standard models of galactic evolution (for example, the Schmidt model in which star formation goes as gas density squared). It appears that if the star formation rate is high enough to produce the stars we see around us, then the nucleosynthesis rate is large enough to produce the processed nuclei (except ^{4}He) seen in those stars. The typical nucleosynthesis source is massive ($M \gtrsim 30 M_\odot$); the estimated death rate of such stars is considerably smaller (by a factor of 0.03 to 0.1) than recent estimates of the total rate of supernovae.

TABLE 1. ESTIMATED YIELDS (IN $M_\odot$) FOR STARS OF VARIOUS MASSES

M_α	M	He	C	O	Ne	Mg	Si+Fe	Core
3	10	1.52	.048	.004	0.	0.	0.	1.42
4	12	2.04	.192	.167	.040	.066	.101	1.38
6	16	2.58	.288	.774	.426	.254	.265	1.41
8	22	3.10	.568	1.66	.767	.270	.339	1.30
12	28	3.59	1.22	3.84	1.04	.311	.424	1.58
16	35	4.06	1.62	6.16	1.42	.405	.979	1.36
24	50	5.02	2.30	11.7	1.98	.624	.934	1.44
32	75	8.62	2.05	16.6	2.35	.970	1.19	2.23
48	95	8.16	3.07	30.3	3.36	1.57	1.79	0.

TABLE 2. DIMENSIONLESS YIELD PER GENERATION

Constituent	Estimated Yield			Solar System (by mass)
	α = 4/3	7/3	10/3	
He	2.5(-2)	1.4(-2)	4.3(-3)	2.4(-1)
C	5.3(-3)	2.0(-3)	6.0(-4)	4.5(-3)
O	2.0(-2)	5.8(-3)	1.7(-3)	1.1(-2)
Ne	4.9(-3)	1.8(-3)	5.3(-4)	1.2(-3)
Mg	2.0(-3)	8.4(-4)	2.6(-4)	5.6(-4)
Si+Fe	2.2(-3)	1.1(-3)	3.4(-4)	2.0(-3)
z	3.4(-2)	1.2(-2)	3.4(-3)	1.9(-2)