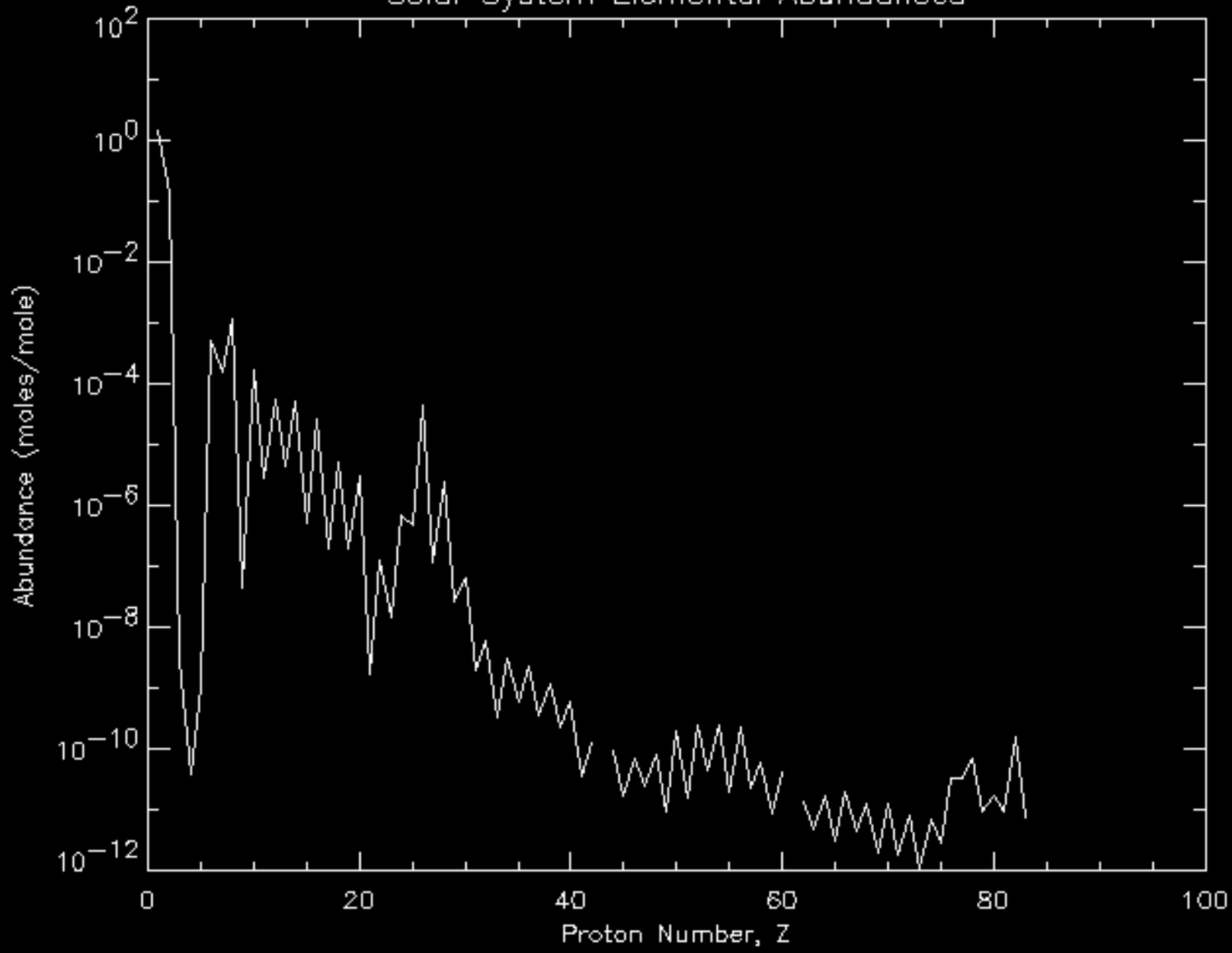
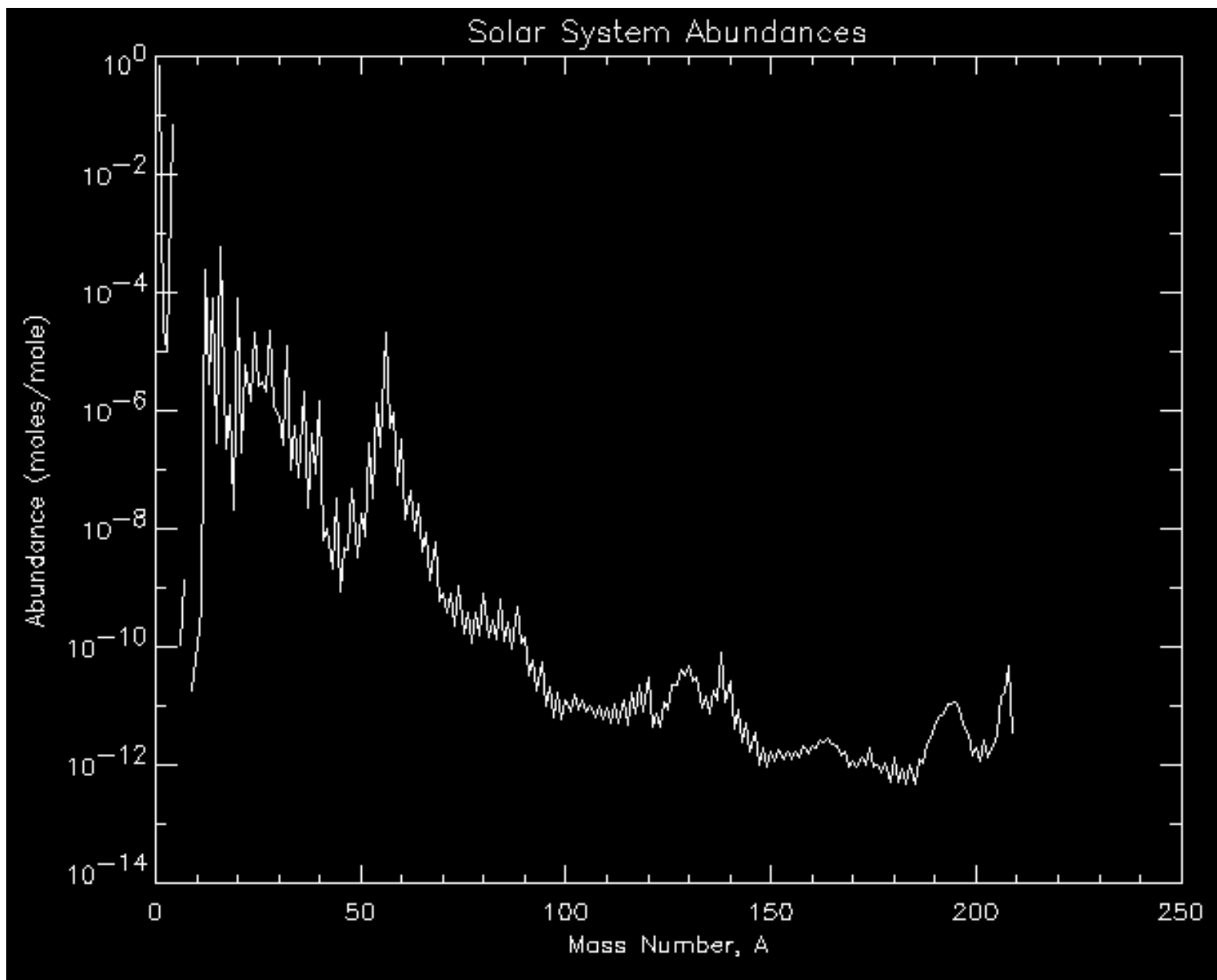


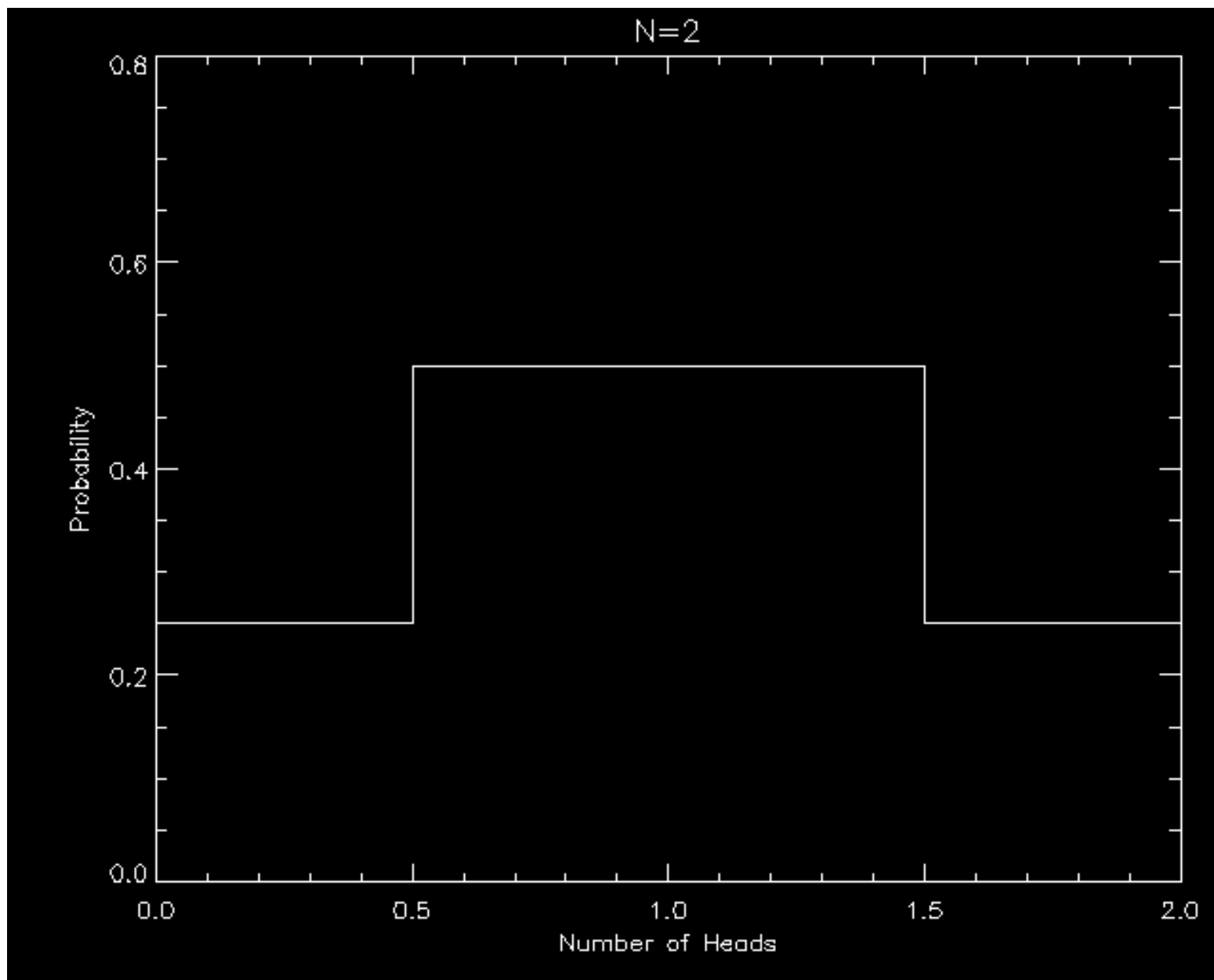
Solar System Elemental Abundances

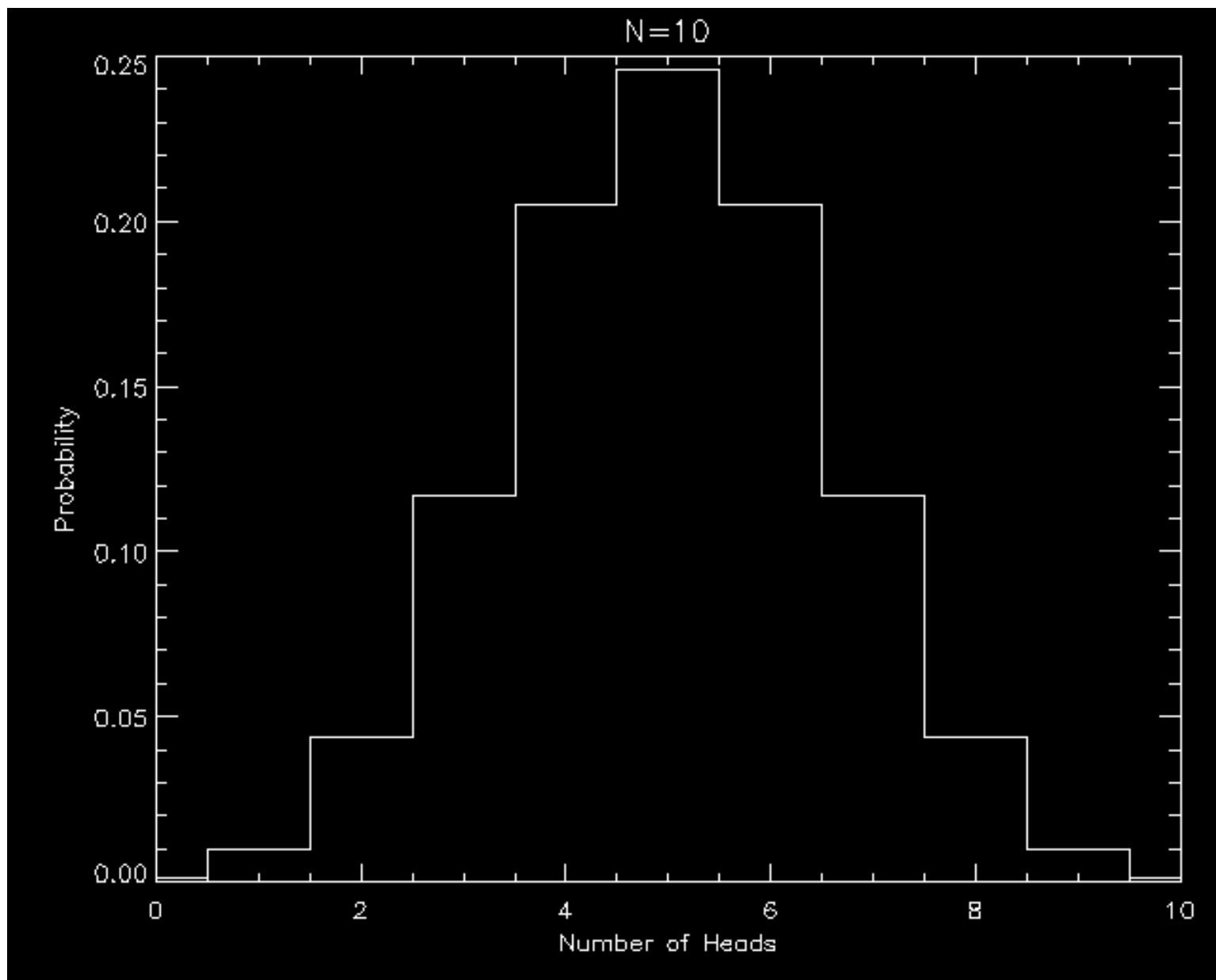


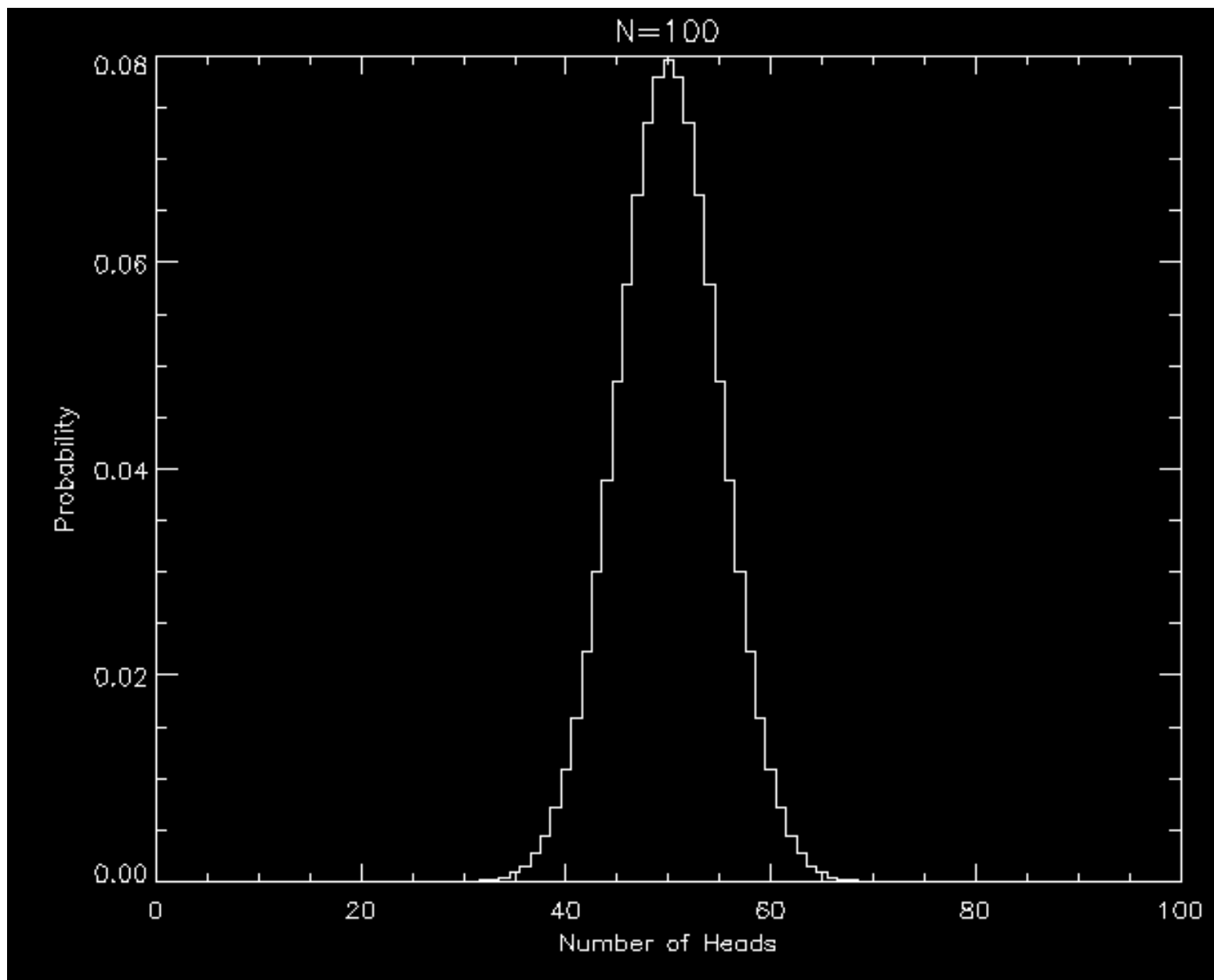


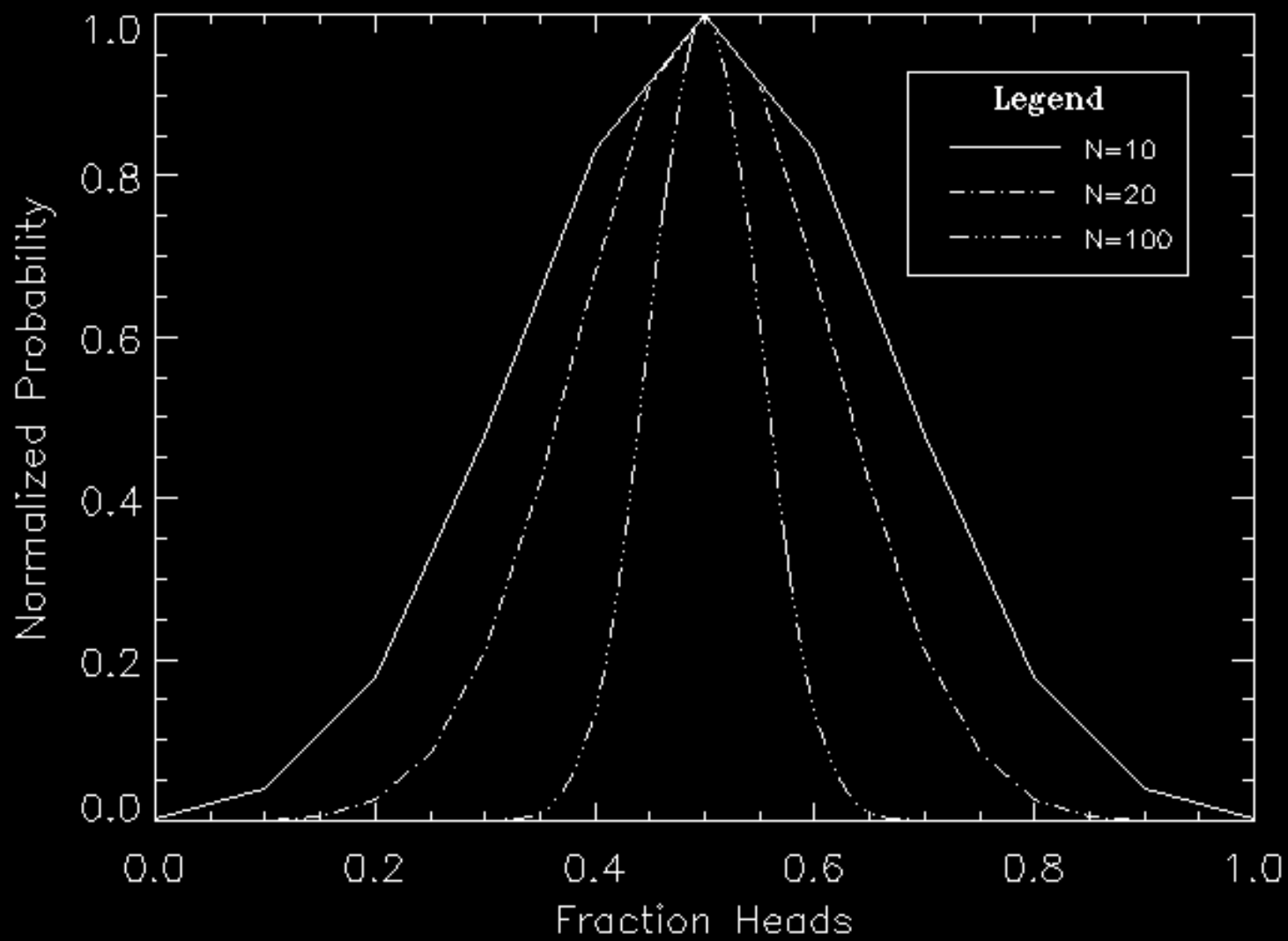
Equilibrium means all allowed
states are equally likely!

Paradox of statistical mechanics: toss out
nearly all information about a system but
get a good description of it!







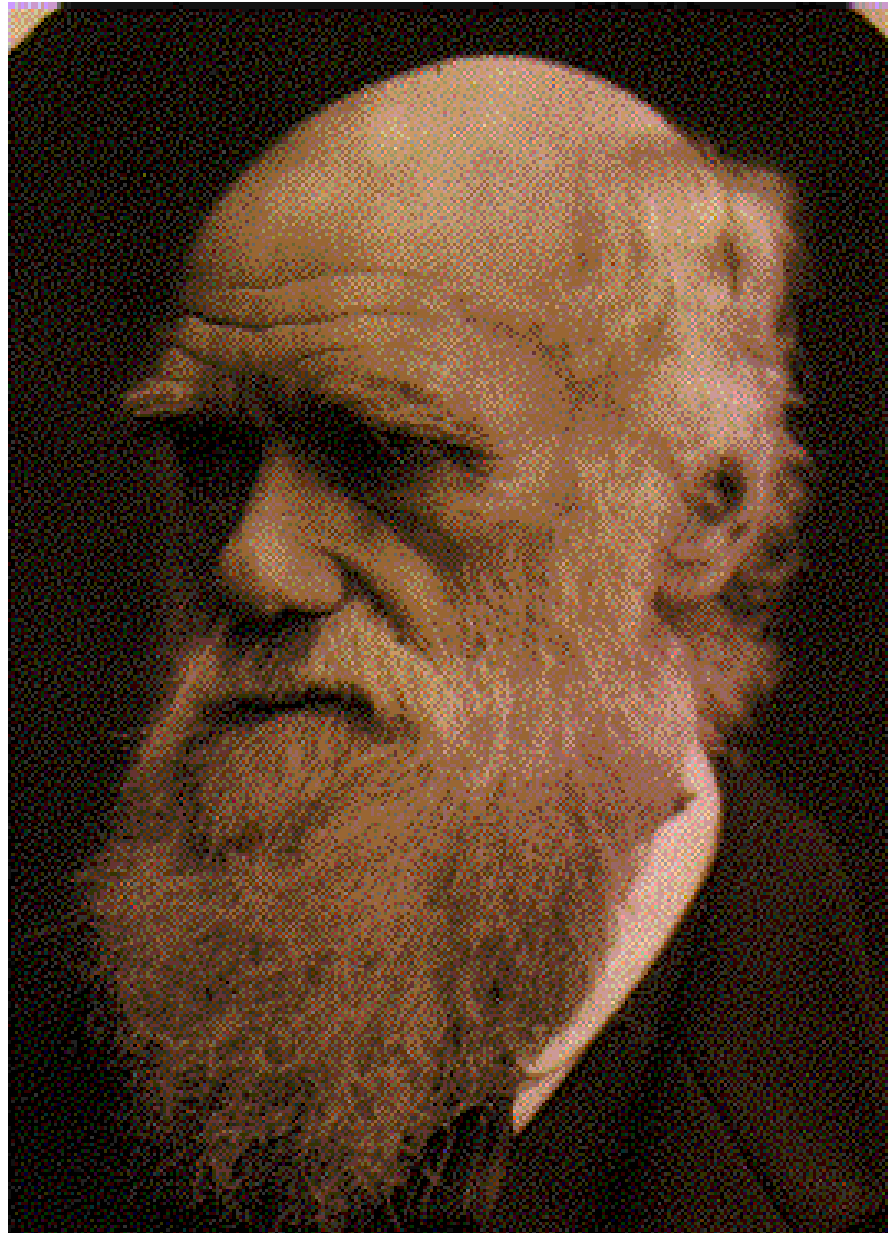


System looks like the most
probable state

$$S = k \log(\text{multiplicity})$$

so maximize the multiplicity, or,
equivalently, the entropy

Most abundant species is the
“fittest”



Fitness of Nuclear Species

- Binding energy per nucleon
- Neutron richness
- Availability of excited states
(increased multiplicity)

Binding Energy: $B(Z,A)$

- $B(Z,A) = Z m_p c^2 + (A-Z) m_n c^2 - m(Z,A)c^2$
- Energy to completely to take the nucleus apart into its constituent nucleons
- Mass excess (in MeV):
$$\Lambda(Z, A) = m(Z, A)c^2 - 931.478A$$

Abundances

- Define abundance per nucleon Y of species and mass fraction X :

$$Y = n / \rho N_A$$

$$X = AY$$

Neutron Richness

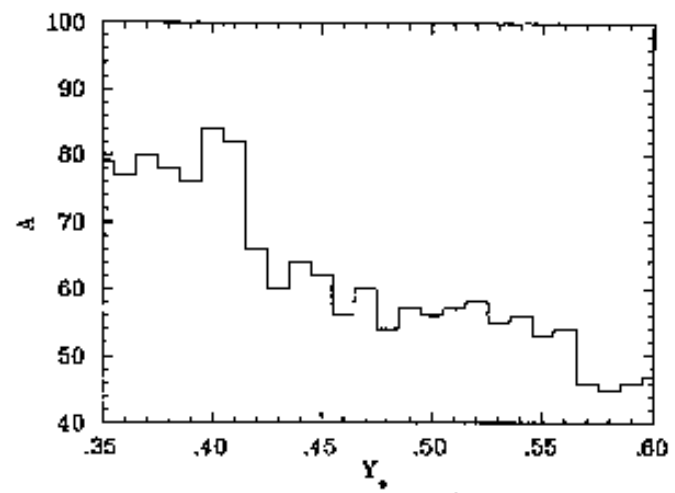
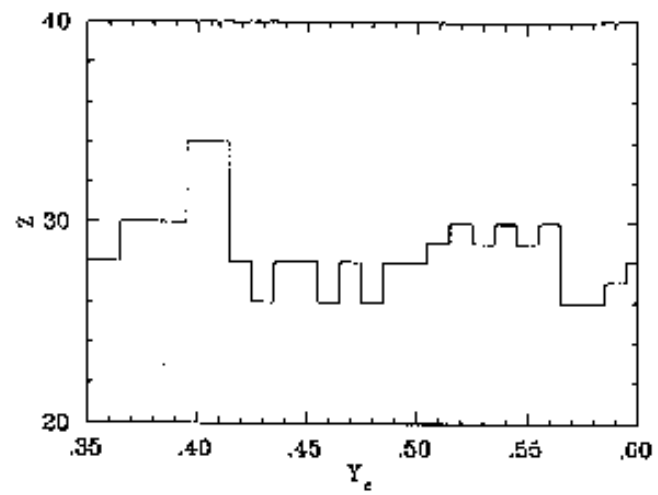
- Quantified by Y_e :

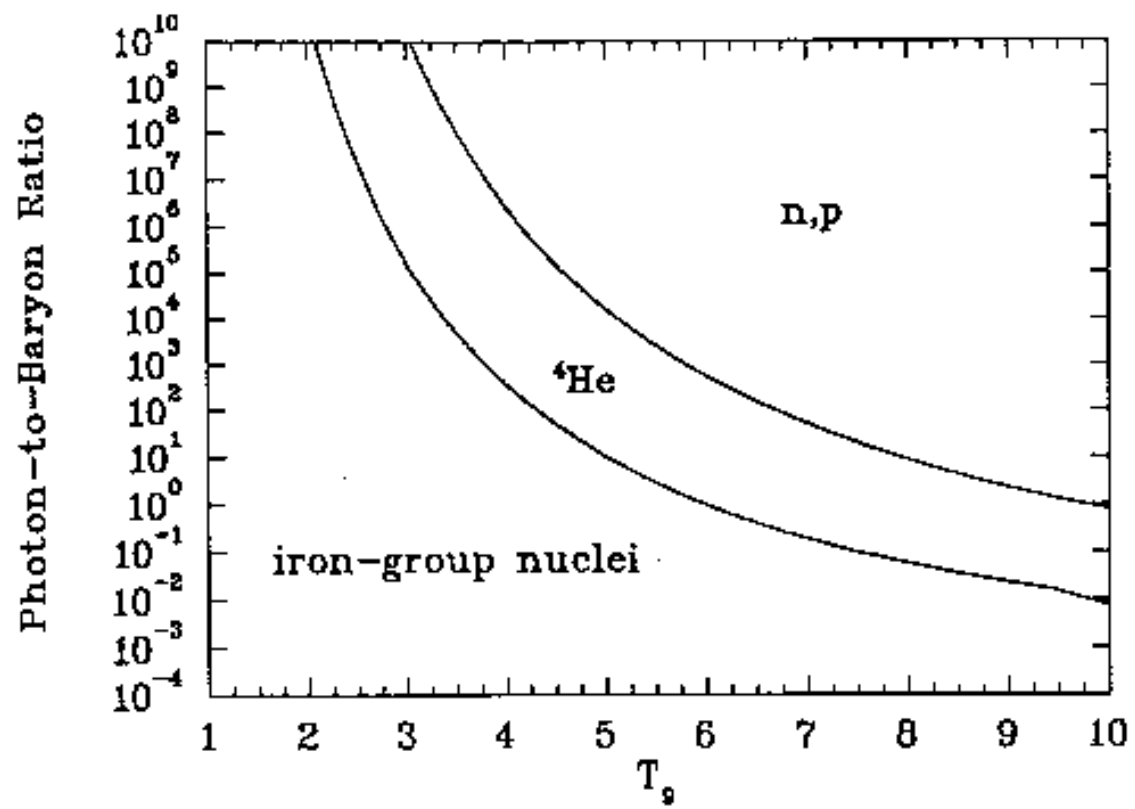
$$Y_e = \sum_i Z_i Y_i$$

Partition Function

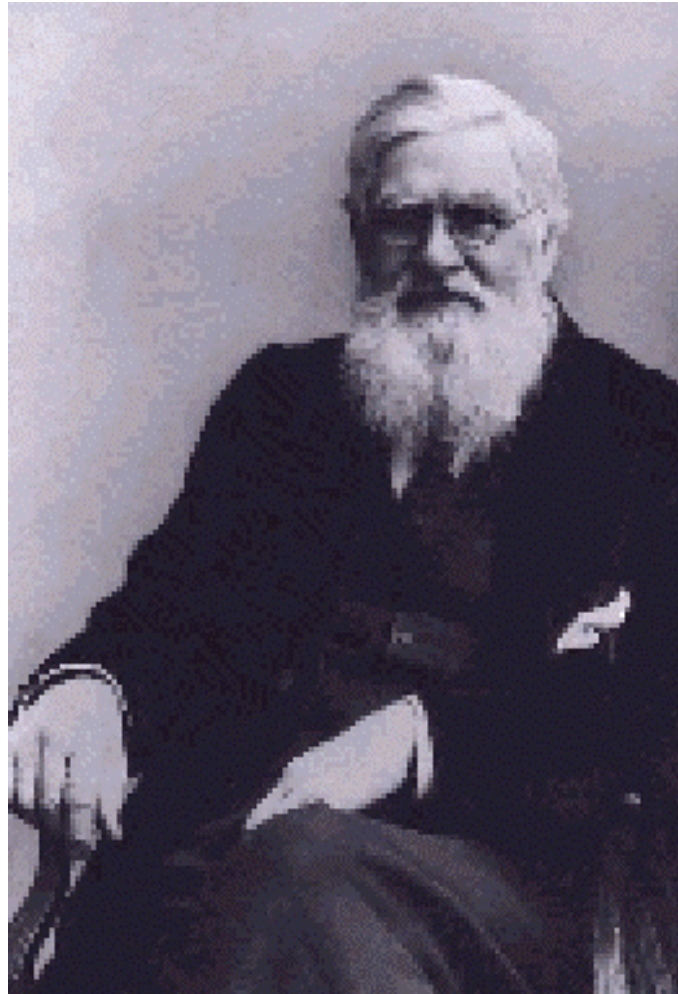
- Partition function G accounts for the multiplicity of a species:

$$G = \sum_i (2J_i + 1) e^{-E_i / kT}$$





Alfred Russel Wallace



Hierarchy of Statistical Equilibria in Nucleosynthesis

(0) Equilibrium with nonconstant nucleon number

(1) NSE with weak equilibrium

(2) NSE with fixed Y_e

(3) QSE (equilibrium with fixed Y_e and Y_h)

(4) Two QSE clusters (equilibrium with fixed Y_e , Y_{h1} , and Y_{h2})

(5) Three QSE clusters (equilibrium with fixed Y_e , Y_{h1} , Y_{h2} , and Y_{h3})



More constraints on system

Physically possible equilibria in nucleosynthesis
(constant nucleon number)

More disorder in system