The Birth of the First Elements

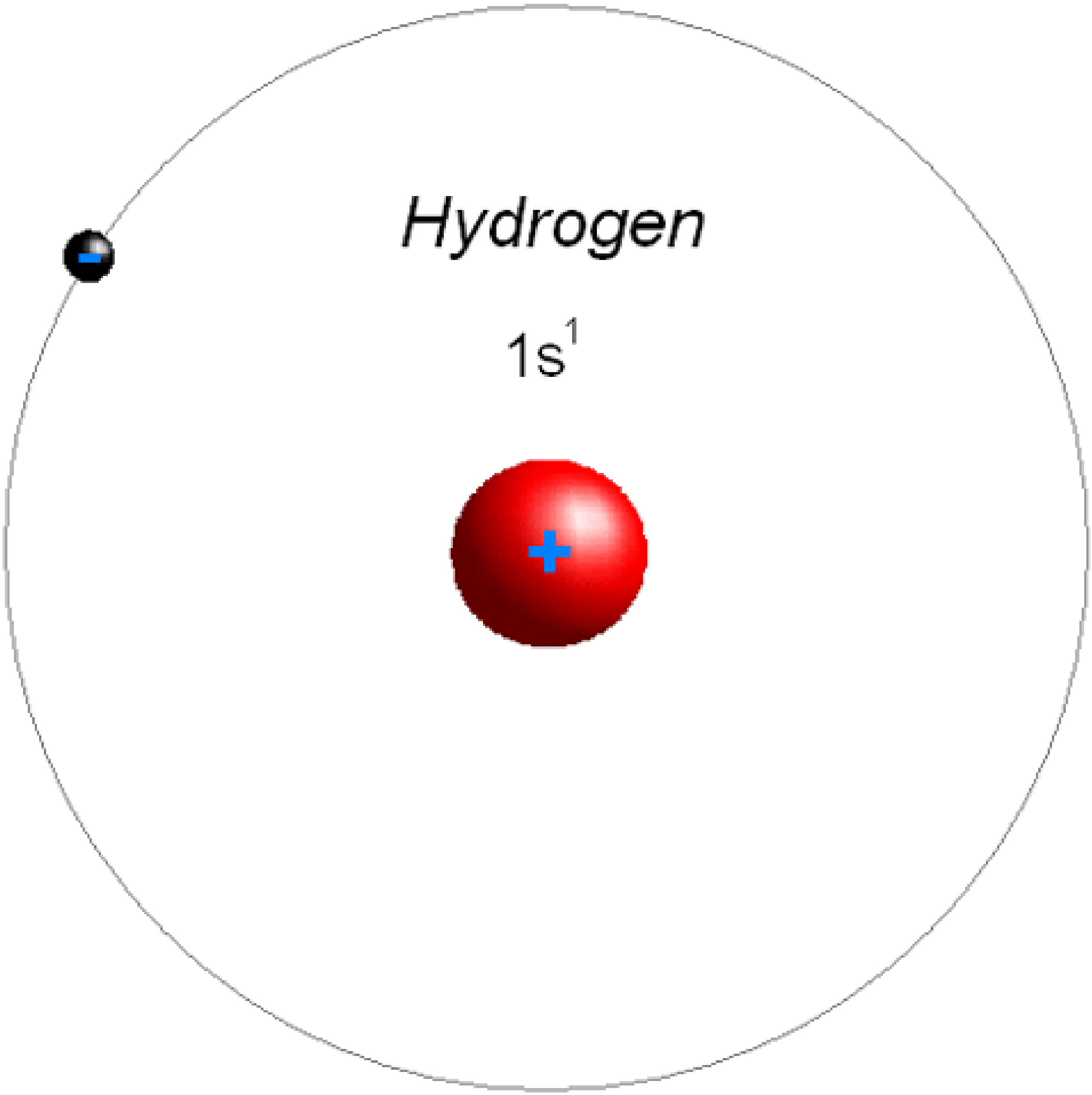
THE LITHIUM CONUNDRUM

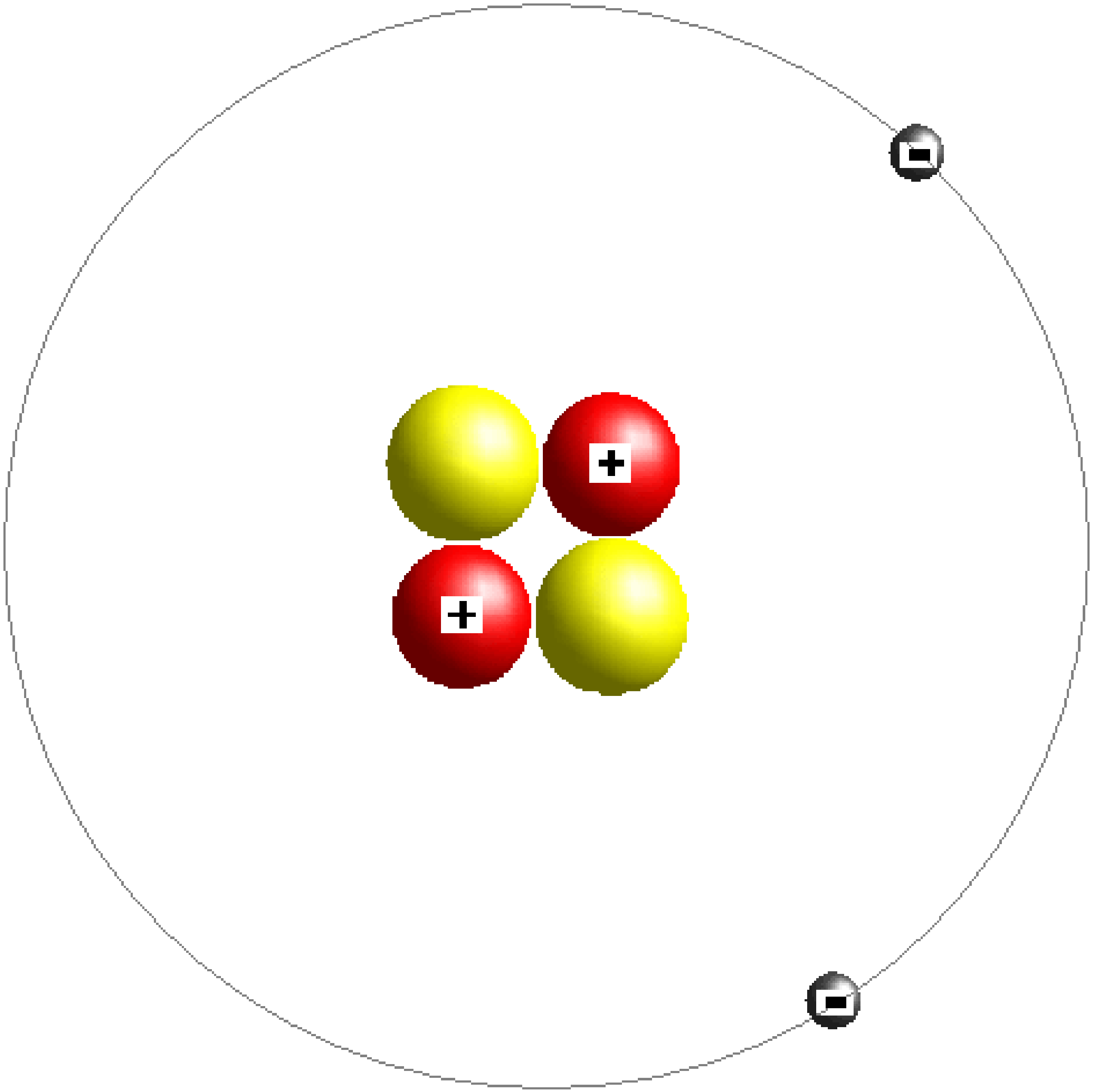
Abergavenny Astronomy Society

Periodic Table of the Elements

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]


Hydrogen
1s1



Helium atom

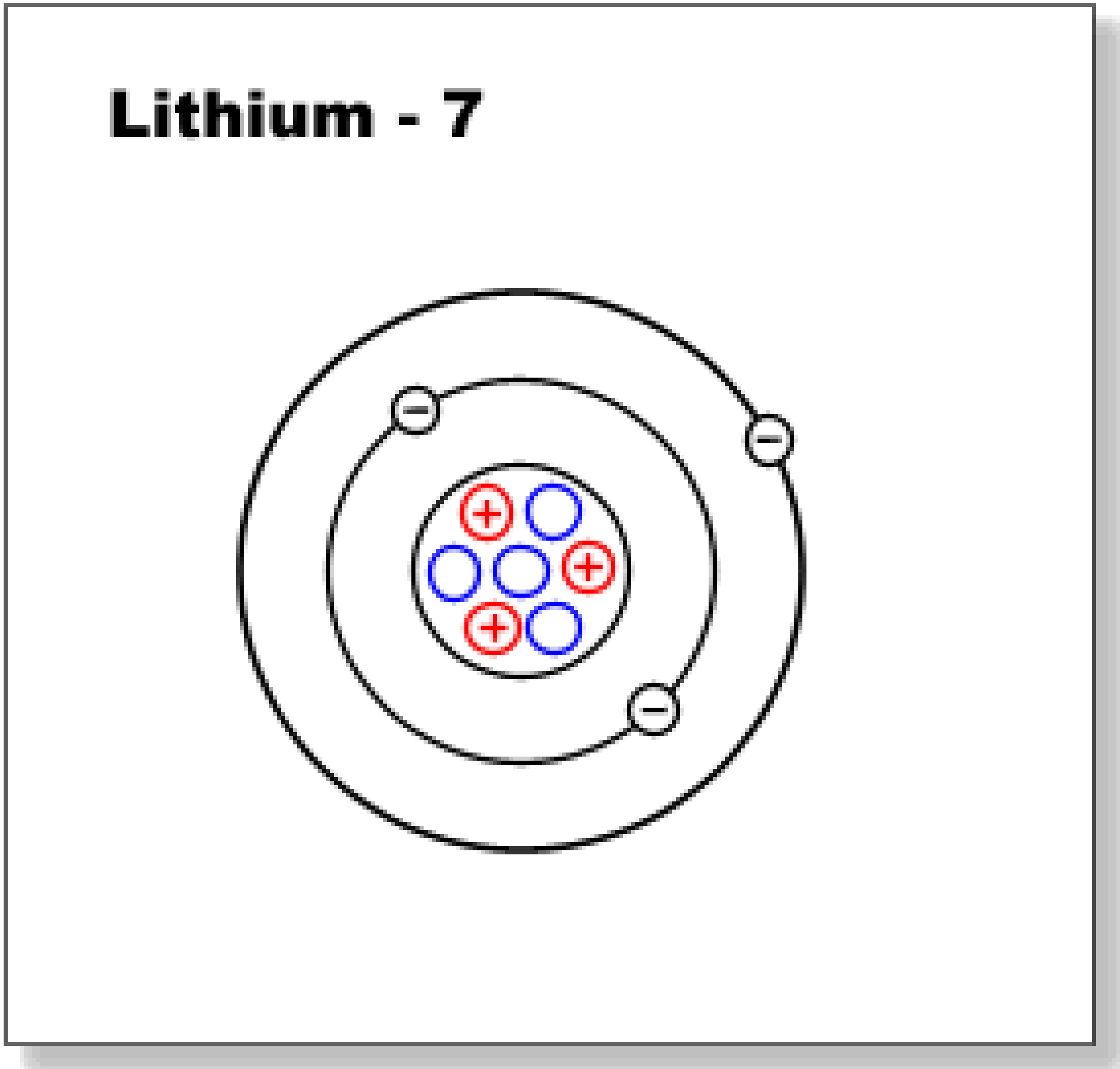
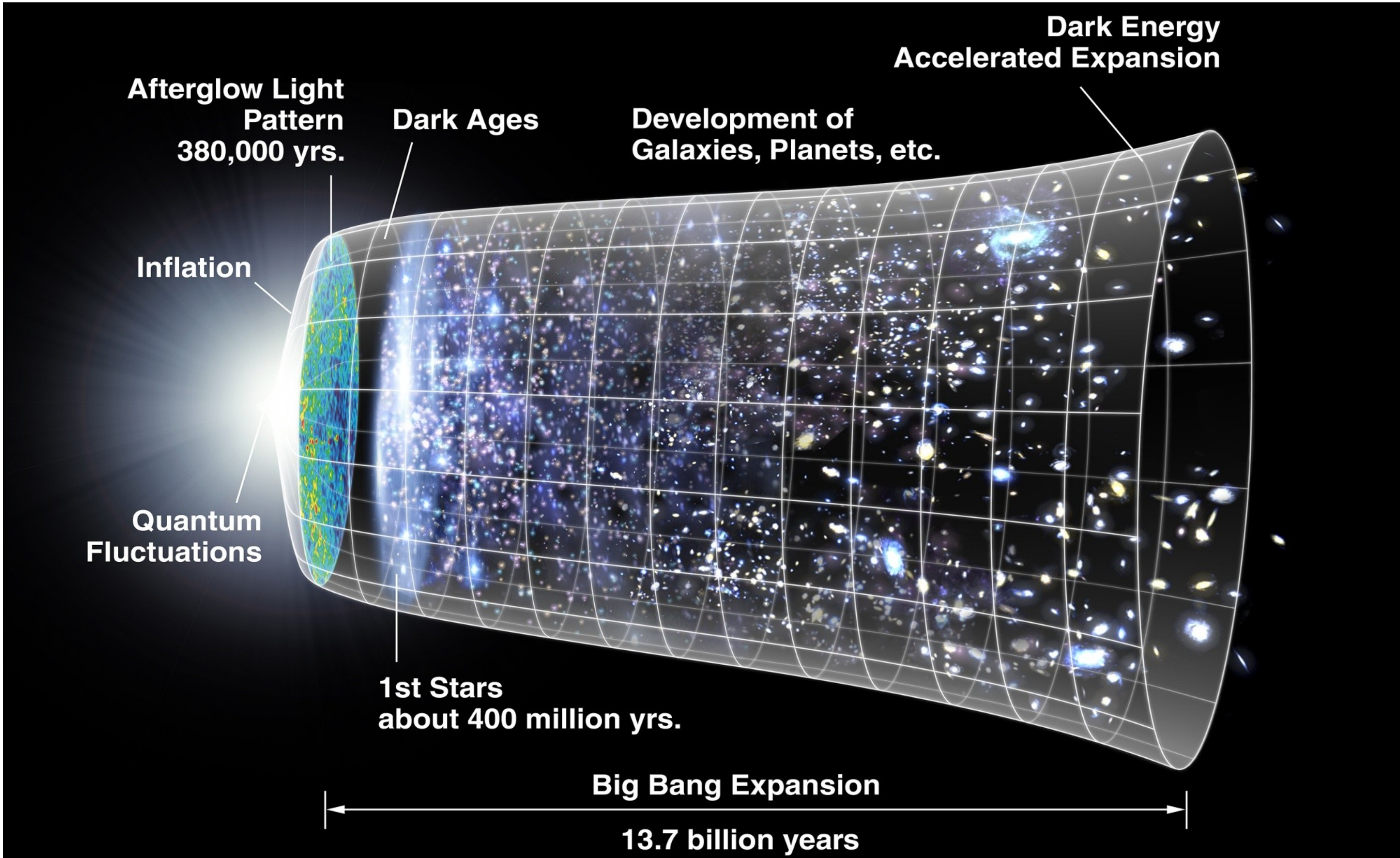


Figure 4

Universal Timeline



The Origin of Chemical Elements

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AND

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AND

G. GAMOW
The George Washington University, Washington, D. C.

February 18, 1948

In their original paper and follow up articles Alpher, Betha and Gamow:

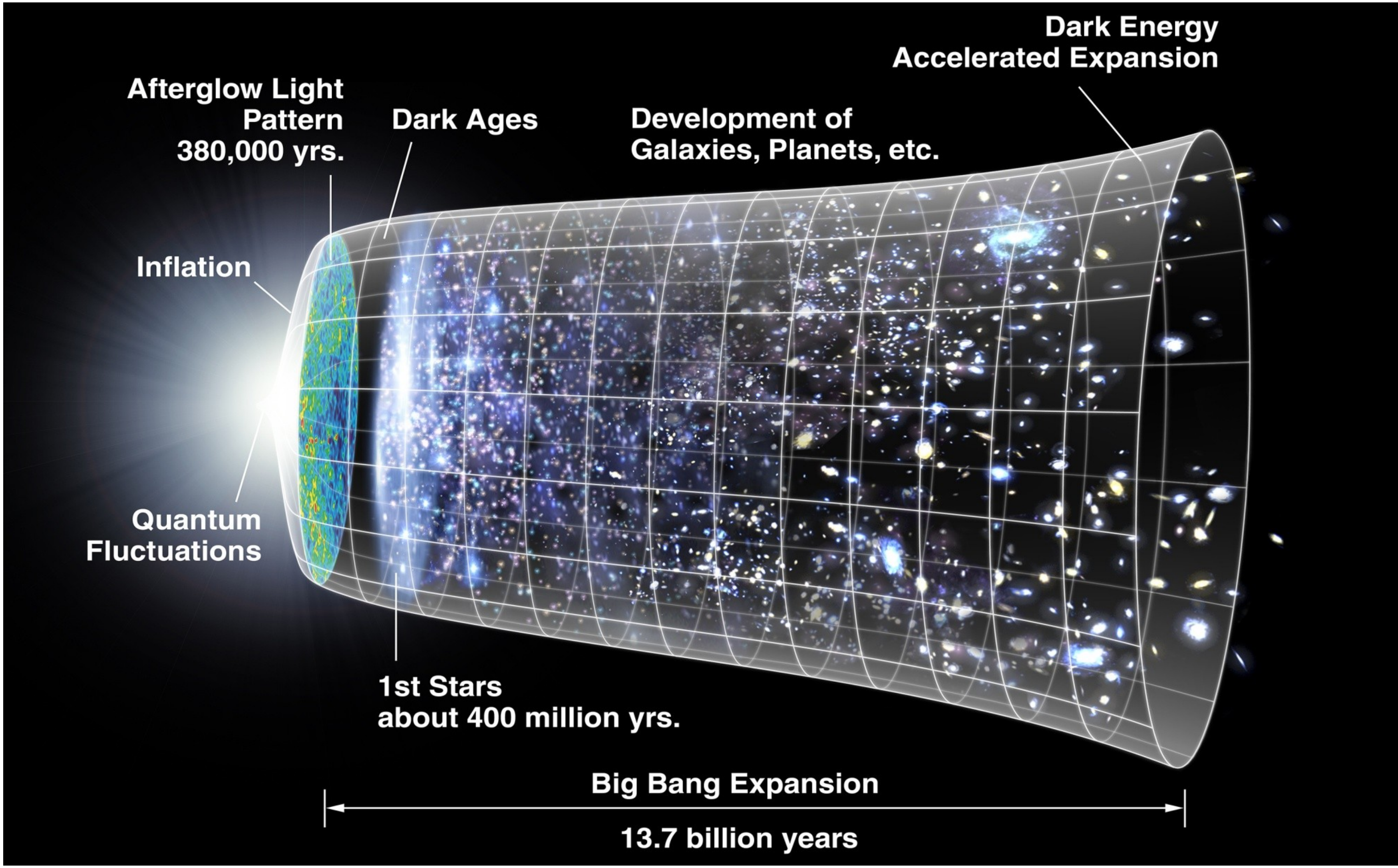
Formulated the theory of "Big Bang Nucleosynthesis "

as opposed to Stellar Nucleosynthesis

Calculated that BBN was completed by 13 minutes after the Big Bang.

current models and observations calculate this to have been completed 10 – 20 minutes after the big bang.

Universal Timeline



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At this temperature, nucleosynthesis, or the production of light elements, could take place.

Big Bang Nucleosynthesis

(or **primordial nucleosynthesis**, abbreviated BBN) refers to the production of nuclei other than those of H-1 (i.e. the normal, light isotope of hydrogen, whose nuclei consist of a single proton each) during the early phases of the universe.

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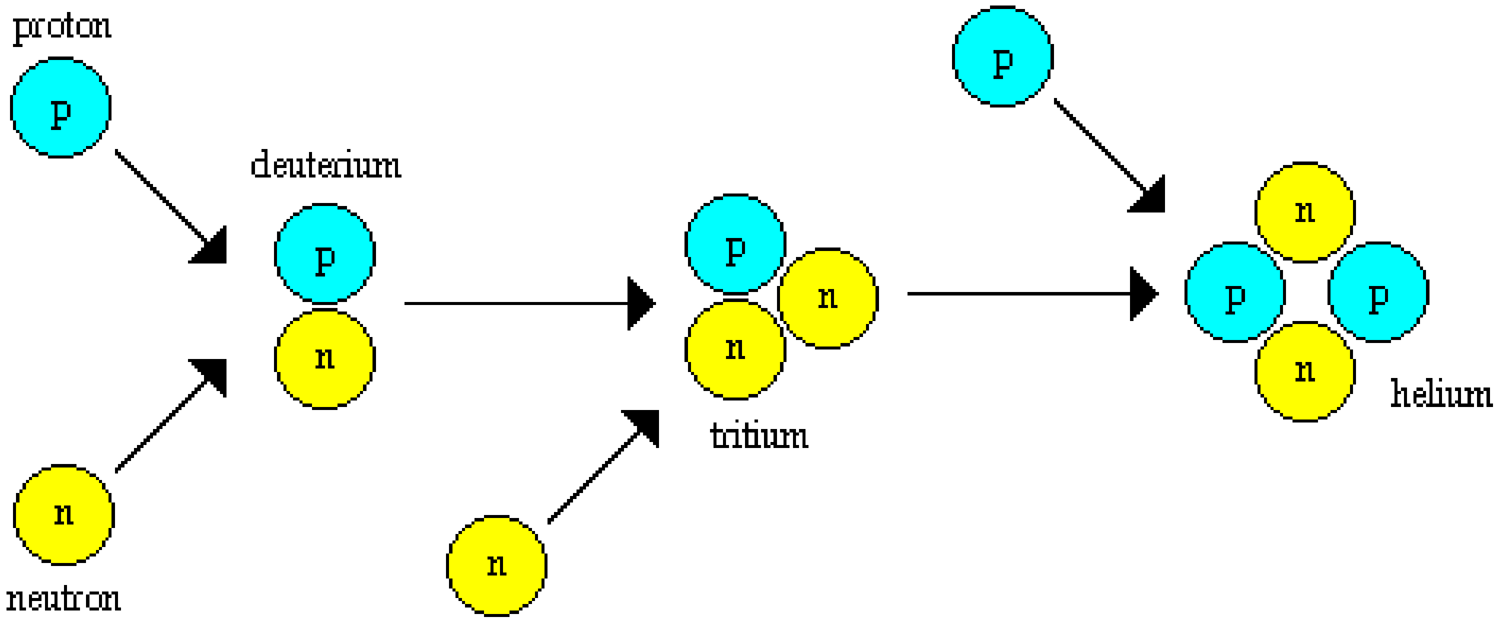
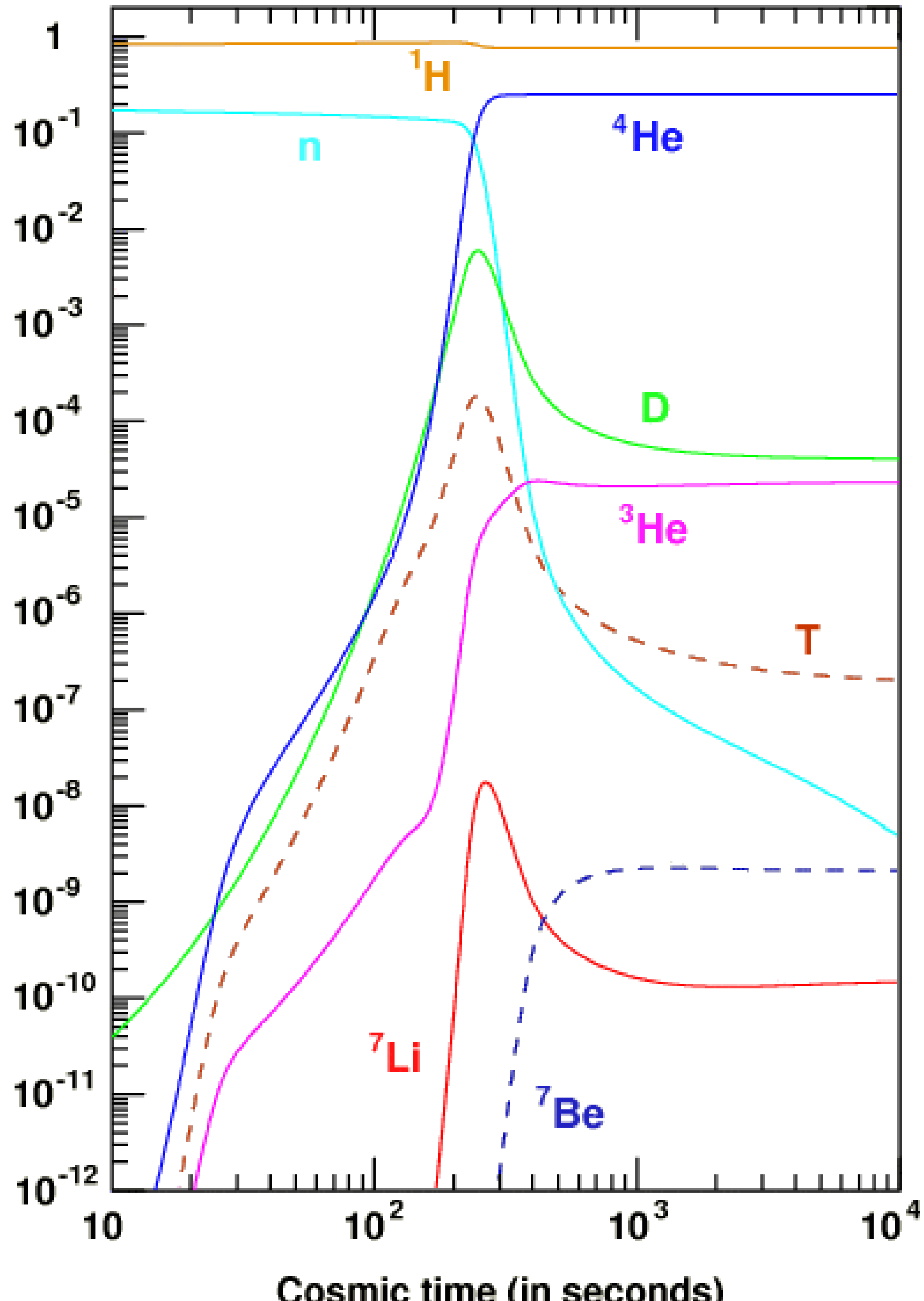
In addition to these stable nuclei some unstable, or radioactive isotopes were also produced during the BBN: tritium H-3; beryllium (Be-7), and beryllium-8 (Be-8). These unstable isotopes either decayed or fused with other nuclei to make one of the stable isotopes.

Nucleosynthesis

as the Universe cools, protons and neutrons can fuse to form heavier atomic nuclei





1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
^{1}H
n
^{4}He
D
^{3}He
T
^{7}Li
^{7}Be
10
10^{2}
10^{3}
10^{4}
Cosmic time (in seconds)

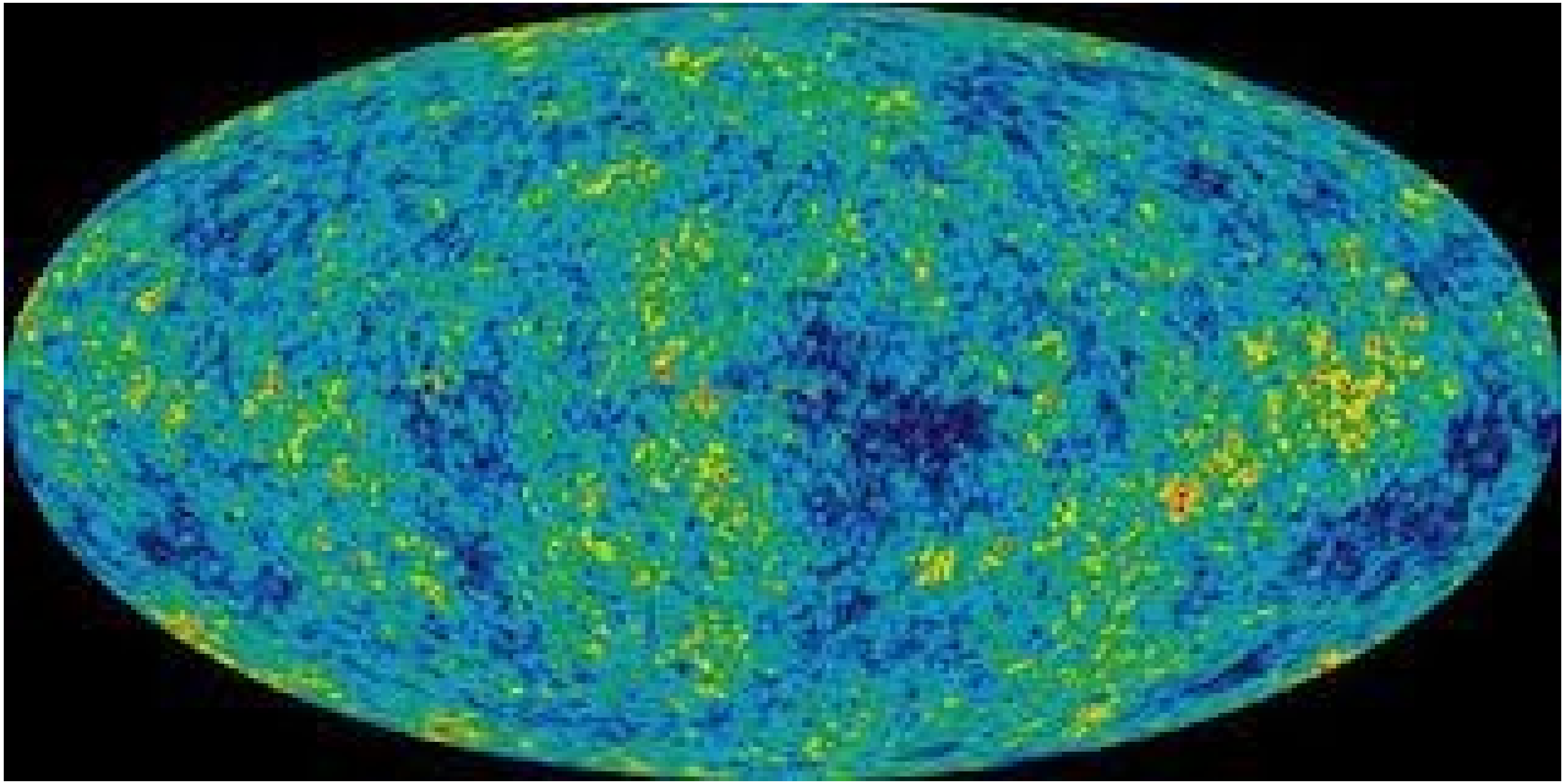
WMAP

Wilkinson Microwave Anisotropy Probe

WMAP was launched on June 30, 2001 from the Cape Canaveral Air Force Base aboard a Delta II rocket.

The WMAP objective was to measure the temperature differences in the Cosmic Microwave Background (CMB) radiation. The anisotropies then are used to measure the universe's geometry, content, and evolution; and to test the Big Bang model, and the cosmic inflation theory.

As of October 2010, the WMAP spacecraft is in a graveyard orbit after 9 years of operations.



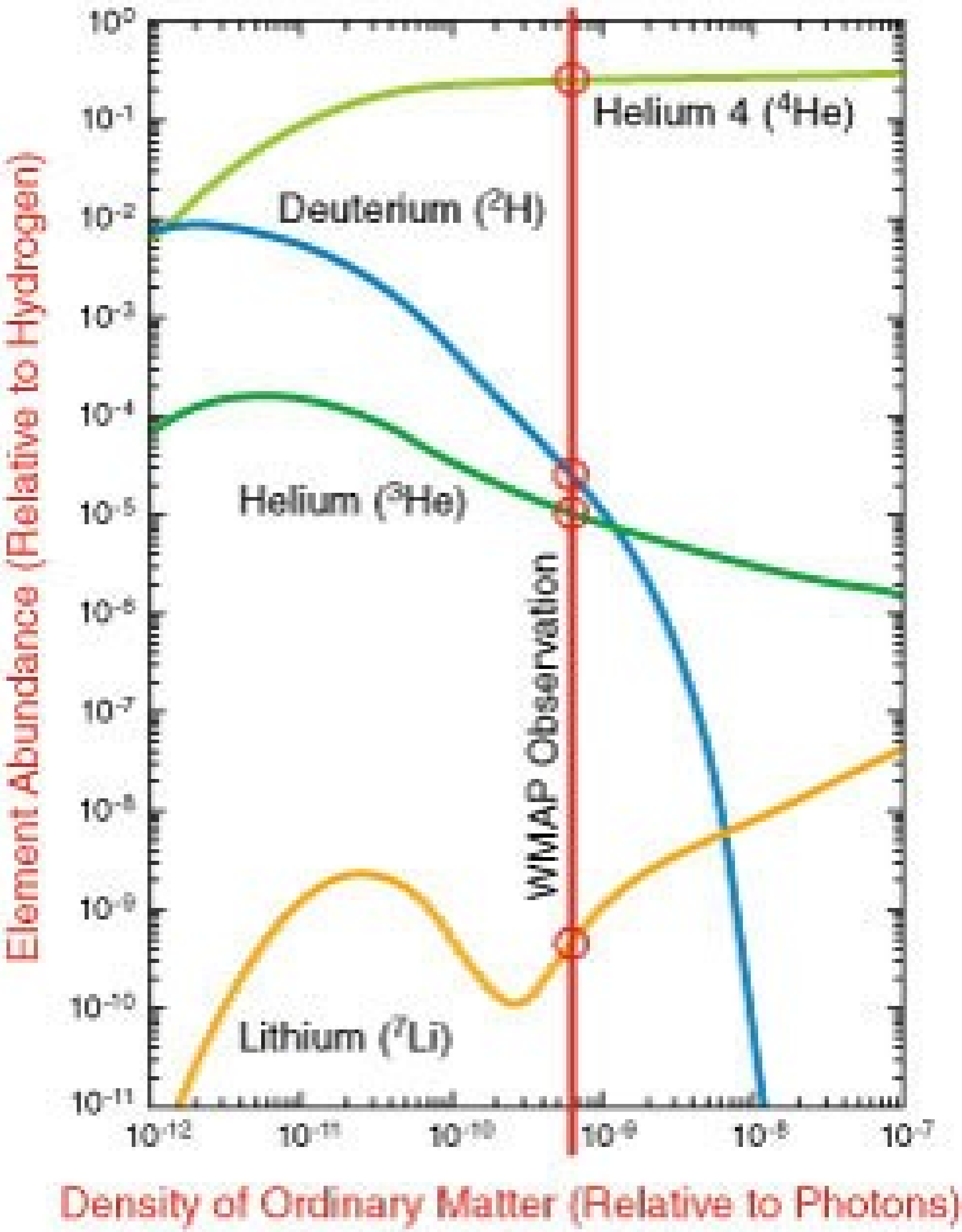
Baryon-photon ratio, (η).

The baryon-photon ratio is a strong indicator of the abundance of light elements present in the early universe. Baryons can react with light elements in the following reactions:

$$(n,p) + 2H \rightarrow (3He, 3H)$$

$$(3He, 3H) + (n,p) \rightarrow 4He$$

It is evident that reactions with baryons during BBN will ultimately result in Helium-4, and also that the abundance of primordial deuterium is indirectly related to the baryon density or baryon-photon ratio. That is, the larger the baryon-photon ratio the more reactions there will be and the more deuterium will be eventually transformed into Helium-4. This result makes deuterium a very useful tool in measuring the baryonic change of the universe.



Helium 4 (^{4}He)
Deuterium (^{2}H)
Helium (^{3}He)
Lithium (^{7}Li)
WMAP Observation
Element Abundance (Relative to Hydrogen)
Density of Ordinary Matter (Relative to Photons)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-11}
10^{-10}
10^{-9}
10^{-8}
10^{-7}

Observation of interstellar lithium in the low-metallicity Small Magellanic Cloud

Christopher Howk, Nicolas Lehner, Brian D. Fields & Grant J. Mathews

Nature 489, 121–123 (06 September 2012)

The primordial abundances of light elements produced in the standard theory of Big Bang nucleosynthesis (BBN) depend only on the cosmic ratio of baryons to photons, a quantity inferred from observations of the microwave background. The predicted
primordial 7Li abundance is four times that measured in the atmospheres of Galactic halo stars. This discrepancy could be caused by modification of surface lithium abundances during the stars' lifetimes or by physics beyond the Standard Model that affects early nucleosynthesis. The lithium abundance of low-metallicity gas provides an alternative constraint on the primordial abundance and cosmic evolution of lithium that is not susceptible to the *in situ* modifications that may affect stellar atmospheres. Here we report observations of interstellar 7Li in the low-metallicity gas of the Small Magellanic Cloud, a nearby galaxy with a quarter the Sun's metallicity.

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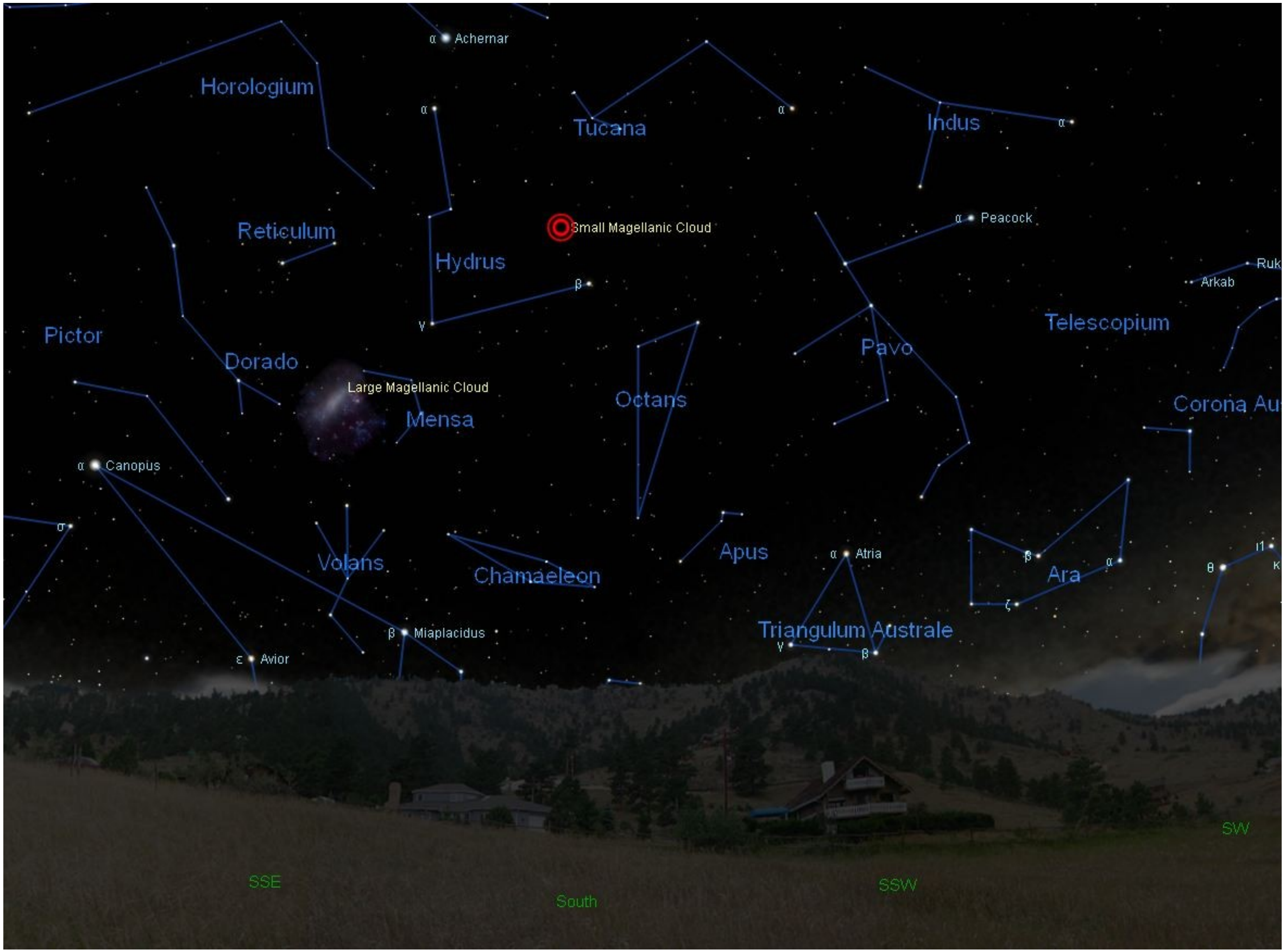
The stars have approximately one quarter the heavier element abundance than our own star.



Achernar
Horologium
Tucana
Indus
Reticulum
Hydrus
Small Magellanic Cloud
Peacock
Arkab
Telescopium
Pictor
Dorado
Pavo
Large Magellanic Cloud
Mensa
Octans
Canopus
Volans
Chamaeleon
Apus
Atria
Ara
Triangulum Australe
Miaplacidus
Avior
SSE
South
SSW
SW

Relative Abundance of Lithium (Li/H)			
Traditional Model	“Early” Spectral Analysis	WMAP	Recent Paper
10-9	2 -3 x 10 -10	2.4 x 10-10	10 – 8.99 (±0.13)

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