XVII. Various Estimates of Age, Mass, and Density of Universe

JADES CMB Mesurement*, H_{0JDC} $\quad H_{0JDC} := 71\,\frac{km}{s\cdot Mpc} \qquad \frac{1}{H_{0JDC}} = 13.765\cdot Gyr$

TWK Local Estimate, H_{twk}** $\quad H_{twk} = 68.55\cdot\frac{km}{s\cdot Mpc} \qquad \frac{1}{H_{twk}} = 14.257\cdot Gyr$

CMB Recombination Redshift/Cooling:
See Section IV. Equation of State $\quad T_{rec}(z) := 2.7250\cdot z \qquad z_{CMB} := \frac{3000}{2.725} \qquad z_{CMB} = 1101 \qquad t_{CMB} := 13.8Gyr$

Critical Density, ρ_0

$$\rho_0 := 8.6443584621592\cdot 10^{-27}\cdot kg\cdot m^{-3}$$

Matter-Radiation Equality: $\quad H_{M\gamma}^2 = (8\pi G/3)\,\rho \qquad H_{M\gamma} := \sqrt{\frac{8\pi G}{3}\rho_0} \qquad \frac{1}{H_{M\gamma}} = 14.414\cdot Gyr$

Hubble Constant from Gravitation Waves:
See Section XV. Standard Candles $\quad H_{grav} := 70\,\frac{km}{s}\,Mpc^{-1} \qquad Age_g := \frac{1}{H_{grav}} \qquad Age_g = 13.962\cdot Gyr$

Estimate Lifetime of the Sun, $Age_\odot$ $\qquad Age_\odot := 10.8Gyr$

See Section XIIC. $\quad M_{glxy} := 2\cdot 10^{41} kg \qquad r_{glxy\odot} := 26000 Lyr$

***Sun's/Earth'a Galactic Years*, $GalYr_\odot$**
Number of time the sun orbited Milky Way

$$v_\odot := \sqrt{G\cdot\frac{M_{glxy}}{r_{glxy\odot}}} \qquad v_\odot := 220\,\frac{km}{s} \qquad GalYr_\odot := \frac{0.4 Age_\odot\cdot v_\odot}{2\cdot\pi\cdot r_{glxy\odot}} \qquad GalYr_\odot = 19\ \ Yrs_{glxy}$$

Estimates of Age of Globular Clusters, Age_{GC} $\qquad Age_{GC} := 10Gyr$

See Section XIII.

Age of White Dwarfs from Cooling Curves
of Local Galactic Disk*, Age_{WD}** $\qquad Age_{WD} := 8Gyr$

Numerical Modeling of Thermochemically Driven Fluid Flow
With Non-Newtonian Rheology Applied to the Earth's Mantle, Age_{cool} $\qquad Age_{cool} := 4.5Gyr$

$t_{est} := 4.8Gyr$

Half-Life of Uranium:

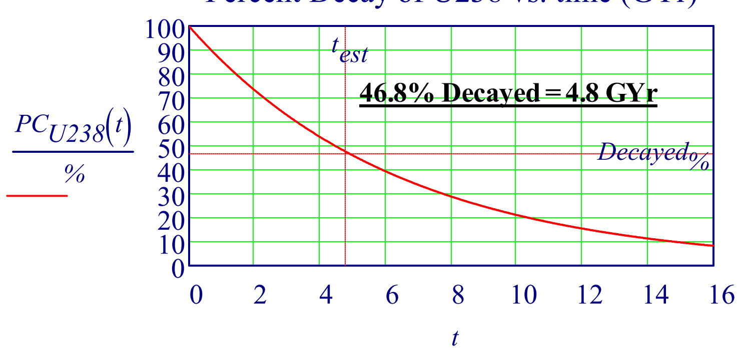
Percent Decay U_{238}, $PC_{U238} = N(t)/N_0$

$$PC_{U238}(t) := \left(\frac{1}{2}\right)^{\frac{t\cdot Gyr}{t_{½Ur238}}} 100\%$$

Half Life U238: $\quad t_{½Ur238} := 4.47Gyr$

%U238 Decayed: $\quad Decayed_\% := 46.8$

Percent Decay of U238 vs. time (GYr)



Roche Limit - Time of Recession of Moon **** $\qquad Age_{recession} := 1.3Gyr$

Parallax Distance, Event Horizon Telescope:
See Section X. Black Hole, Messier M87* $\qquad$ Parallax Distance: $d_\pi\left(10\cdot 10^{-3} arcsec, b\right) = 37368\cdot lightyear$

* *XXIV. JADES: Lookback Time versus Red Shift and Age of Univ z = 13.2* Gyr
** *XIV. A. Current Value of Hubble's Law, H0. Data: NASA Galaxy Recession from 3645 Galaxies*, TWK
*** *The Cool White Dwarf Luminosity Function And the Age of the Galactic Disk*, S. K. Leggett

**** *Tidal Recession Of The Moon From Ancient And Modern Data,* F. R. Stephenson, 1981

Measuring the of Age of the Universe - Globular Clusters

- Could place a lower limit from the **ages of astrophysical objects** (pref. the oldest you can find). e.g..
  - 1. **Age of Globular clusters** in our Galaxy; known to he very old.
    Need stellar evolution isochrones to fit to color-magnitude diagrams
  - -2. **Age of White dwarfs** from their observed **Luminosity Function** cooling theory and assumed star formation rate
  - 3. **Age of Heavy elements**. produced in the first Supernovae; somewhat model-dependent
  - 4. **Age-dating stellar populations in distant galaxies:**
    this is very tricky and requires modeling of stellar population evolution. with many uncertain parameters.
- Related to the **Hubble time** $t_H = 1/H_0$, but the exact value depends on the cosmological parameters

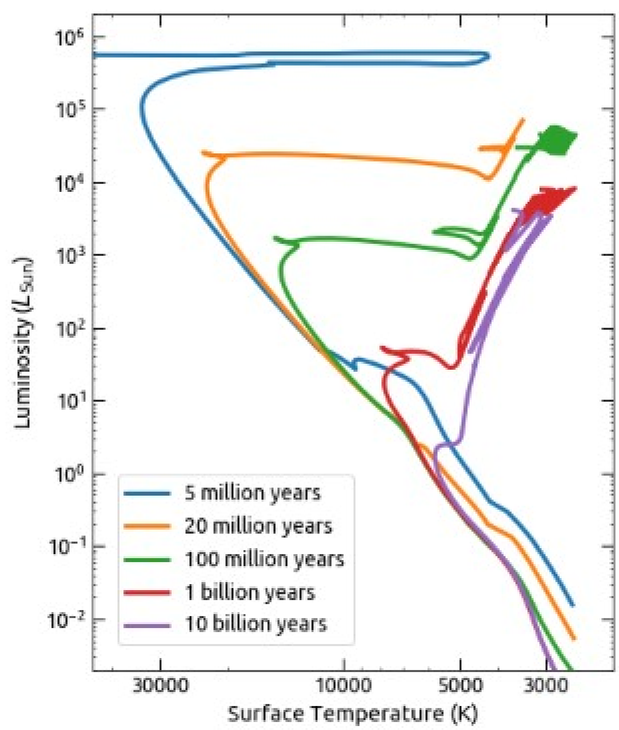
Ages of Globular Clusters

We measure the age of a globular cluster by measuring the **magnitude of the main sequence turnoff** or the difference between that magnitude and the level of the horizontal branch, and comparing this to stellar evolutionary models of which estimate the surface temperature and luminosity of stars as a function of time period
There are a fair number of uncertainties in these estimates, including errors and measuring the distances to the GC's, and uncertainties in the isochrones used to drive ages, that is, stellar evolutionary models.

Inputs to stellar evolution models include oxygen abundance [O/Fe] treatment of convection, He abundance, reaction rates of N + p O plus gamma. Heat diffusion, and conversions from theoretical temperatures and luminosity to observed colors and magnitudes, and opacities; and especially **distances.**

Wikipedia- Stellar Isochrone

"In stellar evolution, an isochrone is a curve on the Hertzsprung-Russell diagram, representing **a population of stars of the same age but with different mass**.The Hertzsprung-Russell diagram plots a star's luminosity against its temperature, or equivalently, its color. Stars change their positions on the HR diagram throughout their life. Newborn stars of low or intermediate mass are born cold but extremely luminous. They contract and dim along the Hayashi track, **decreasing in luminosity but staying at roughly the same temperature**, until reaching the main sequence directly or by passing through the Henyey track. Stars evolve relatively slowly along the main sequence as they fuse hydrogen, and after the vast majority of their lifespan, all but the least massive stars become giants. They then evolve quickly towards their stellar endpoints: white dwarfs, neutron stars, or black holes.
Isochrones can be used to date open clusters because their members all have **roughly the same age**. One of the first uses of an isochrone method to date an open cluster was by Demarque and Larson in 1963.



Theoretical isochrones for **near-solar metallicity** and a range of ages.

If the initial mass function of the open cluster is known, isochrones can be calculated at any age by taking every star in the initial population, **using numerical simulations to evolve it forwards** to the desired age, and plotting the star's luminosity and magnitude on the HR diagram. The resulting curve is an isochrone, which can be compared against the observational color-magnitude diagram to determine how well they match. If they match well, the assumed age of the isochrone is close to the actual age of the cluster."

Estimate Age using Hubble Time and Chemical Element Radioactive Decay

Imagine the Hubble expansion scenario playing like a movie in reverse. Instead of galaxies moving away from each other as time goes forward, galaxies would rush toward each other as time goes backward. Galaxies would be closer and closer together in the past, until at some time in the distant past the matter that makes up the galaxies would have been very close together. We can extrapolate back to this time, the beginning of the Universe. If we know the expansion rate for the Universe and assume that it has been constant, we can run the clock backwards and calculate how much time the Universe has been stretching.
The age of the universe is largely determined by the rate at which it expands, and the current value of the Hubble 'constant' fixes the Hubble time. The Hubble constant is an example of a stretching rate. The Hubble constant is generally expressed in units of km/s/Mpc due to how it is measured. However, both km and Mpc are units of distance and cancel out, so the Hubble constant, or any stretching rate, actually has units of 1/time. Again, assuming that the expansion rate has been constant, **we therefore have an expression for the age of Our Universe.**

$t_{twk\_age\_universe} := \dfrac{1}{H_{twk}}$ $\quad$ $billion := 10^9$ $\quad$ $t_{twk\_age\_universe} = 14.257 \cdot billion \cdot yr$

Estimate from Age of Chemical Elements Using Radioactive with Long Half Lives:
The Allende meteorite is well studied and has an age of 4.554 Gyr.

Estimate of Radius of Curvature of the Universe: (Einstein's Old Static Idealized Model)

Putting $\dot{a} = \ddot{a} = 0$ into the Friedmann Equation, gives the radius of curvature of space in the universe

$\rho_c := 8.644 \dfrac{kg}{m^3} 10^{-27}$ $\quad$ $light\_year := c \cdot yr$ $\quad$ $R_E := \dfrac{c}{\sqrt{4\pi \cdot G \cdot \rho_c}}$ $\quad$ $R_E = 11.77 \cdot light\_year \cdot billion$

XVIIC. Estimate the Lifetime of the Sun

Calculation is Based on the Intensity of Light from Sun and the Amount of Liberated Fusion Energy
Physics of the Sun, Dipak Basu, Chapter 11.3 *Proton Collision Rates in the Sun*

Power to Earth From Sun: $\quad P_{sun\_earth} := 1357 W \cdot m^{-2}$ $\quad$ Total Area of Earth is $4\pi * d^2$

Rate Sun is Burning Energy = Sun's Luminosity: $\quad L_{sun} := P_{sun\_earth} \cdot 4 \cdot \pi \cdot \left(92.027 \cdot 10^6 mile\right)^2$ $\quad$ $L_{sun} = 3.74 \times 10^{26} \cdot W$

What Percent of Mass in Converted: One He atom has less than Mass of 4 H atoms

Particle	Proton	Neutron	2 Protons+2 Neutrons	Alpha	Difference
Units 10^{-27} kg:	1.672621637	1.674927211	6.695097696	6.64465620	0.050441496

$4 \cdot H = He + Energy$ $\quad$ $M_{4p} := 6.692 \cdot 10^{-27} kg$ $\quad$ $M_{He} := 6.644 \cdot 10^{-27} kg$

$M_{lost\_Percent} := \left(M_{4p} - M_{He}\right) \cdot M_{4p}^{-1}$ $\quad$ $M_{lost\_Percent} = 0.717 \cdot \%$

Estimate Sun's Lifetime: Life Time = Total Energy (Esun) to Burn/fuse = Esun / Burn Rate

Only 10% of the mass of the sun is at the core where it is hot enough for fusion to occur

Mass of Sun: $\quad M_{\odot} := 1.989 \cdot 10^{30} kg$ $\quad$ $E_{sun} := 10\% \cdot M_{\odot} \cdot c^2 \cdot M_{lost\_Percent}$

$Billion := 10^9$ $\qquad Life_{sun} := \frac{E_{sun}}{L_{sun}}$ $\qquad Life_{sun} = 10.9 \cdot Billion \cdot yr$

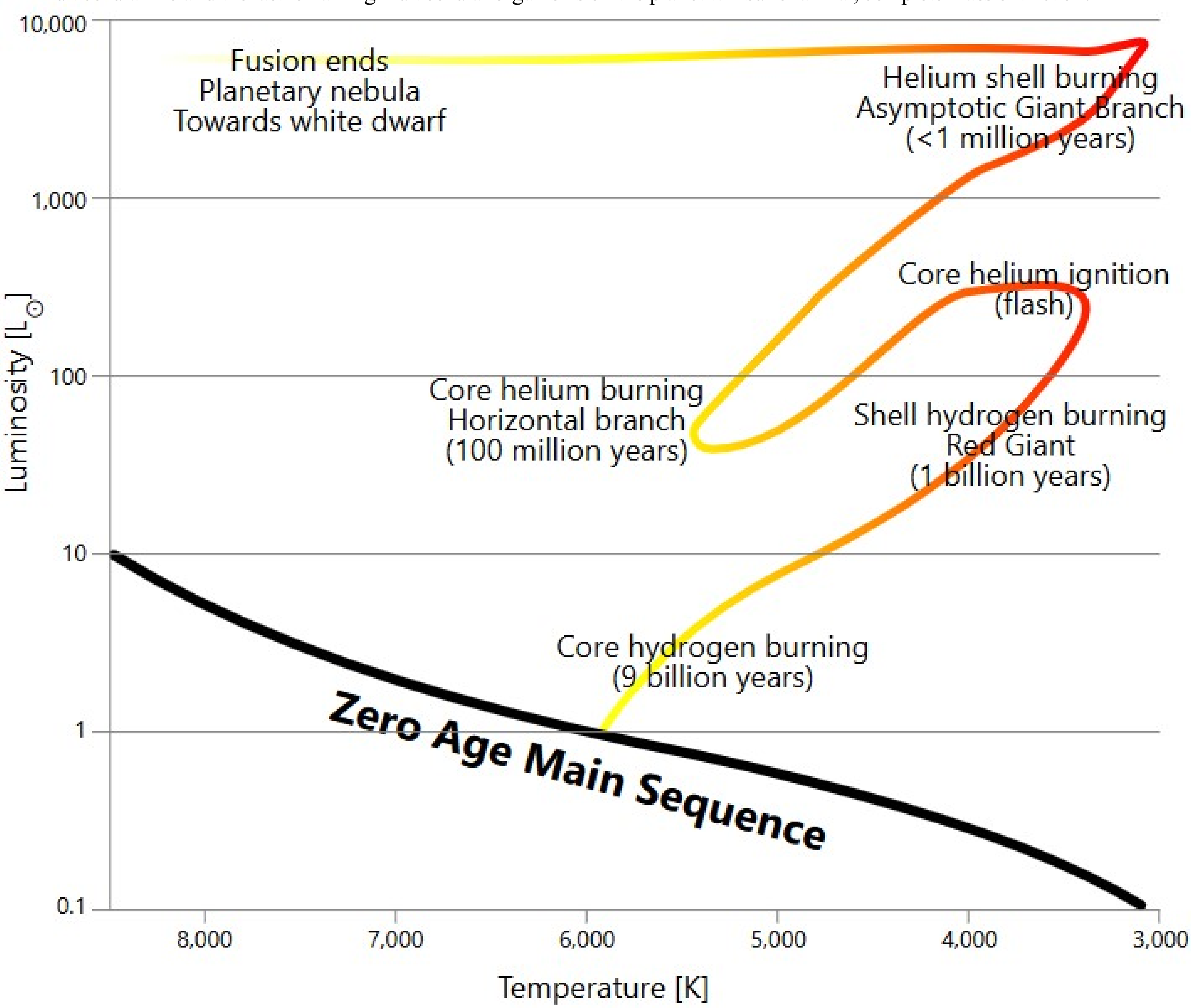
Evolution of the Sun

https://en.wikipedia.org/wiki/Sun

"Evolution of a Sun-like star. The track of a one solar mass star on the Hertzsprung–Russell diagram is shown from the main sequence to the post-asymptotic-giant-branch stage.

The Sun is about halfway through its main-sequence stage, during which nuclear fusion reactions in its core fuse hydrogen into helium. Each second, more than four billion kilograms of matter are converted into energy within the Sun's core, producing neutrinos and solar radiation. At this rate, the Sun has so far converted around 100 times the mass of Earth into energy, about 0.03% of the total mass of the Sun. The Sun will spend a total of approximately 10 to 11 billion years as a main-sequence star before the red giant phase of the Sun. At the 8 billion year mark, the Sun will be at its hottest point according to the ESA's Gaia space observatory mission in 2022.

The Sun is gradually becoming hotter in its core, hotter at the surface, larger in radius, and more luminous during its time on the main sequence: since the beginning of its main sequence life, **it has expanded in radius by 15%** and the surface has increased in temperature from 5,620 K to 5,772 K (9,930 °F), resulting in a **48% increase in luminosity** from **0.677 solar luminosities to its present-day 1.0 solar luminosity**. This occurs because the helium atoms in the core have a higher mean molecular weight than the hydrogen atoms that were fused, resulting in **less thermal pressure**. The core is therefore shrinking, allowing the outer layers of the Sun to move closer to the center, releasing gravitational potential energy. According to the virial theorem, half of this released gravitational energy goes into heating, which leads to a gradual increase in the rate at which fusion occurs and thus an increase in the luminosity. This process speeds up as the core gradually becomes denser. At present, it is increasing in brightness by about 1% every 100 million years. **It will take at least 1 billion years from now to deplete liquid water from the Earth from such increase**. After that, the Earth will cease to be able to support complex, multicellular life and the last remaining multicellular organisms on the planet will suffer a final, complete mass extinction."



Diverse Estimates for Mass and Densities of Matter in the Universe

Estimating the amount of baryonic matter by the number of observable stars

Estimating the amount of baryonic matter in the universe from the number of stars involves several assumptions and simplifications. Stars make up a significant portion of the visible, or baryonic, matter in the universe, but they do not account for all of it. There's also interstellar gas, planets, and other components. Here's a basic approach to such an estimate:

Astronomical Estimate the Number of Stars in the Universe: Current estimates suggest that there are approximately N_{stars} stars in the observable universe. This range is based on the estimated number of galaxies in the observable universe and the average number of stars per galaxy. Number of stars in a typical galaxy (e.g. Milky

$N_{stars\_gal} := 100 \cdot 10^9$ $\quad N_{galaxies} := 2 \cdot 10^{12}$ $\quad N_{stars} := N_{stars\_gal} \cdot N_{galaxies}$ $\quad N_{stars} = 2 \times 10^{23}$

Average Mass of a Star M_{star}: The mass of stars varies widely, but for a rough estimate, you can use the mass of the Sun as an average value. $M_{\odot} = 1.989 \times 10^{30}\,kg$ $\quad M_{tot\_stars} := N_{stars} \cdot M_{\odot}$

Baryonic Mass Inventory for GALAXIES and Rarefied Media
from Theory and **Observations of Rotation (RC) and Luminosity - 2023** $\quad \rho_{BaryonGal\_2023RC} := 6 \cdot 10^{-25} \frac{kg}{m^3}$

Baryonic Content of Visible Universe, Persic, 1992 $\quad \Omega_{b\_stars} := 0.002$ $\quad \Omega_{b\_total} := 0.003$

ρ_{Baryon} for Universe: $\quad \rho_{Baryon} := 3 \cdot 10^{-28} \frac{kg}{m^3}$

$\rho_{Baryon} \cdot \rho_c^{-1} = 0.035$

Adjust for Non-Stellar Baryonic Matter: Stars are not the only form of baryonic matter. There's also interstellar and intergalactic gas, planets, and other forms of matter. To account for this, you can adjust the total mass. Typically, the ***M*ass of stars is estimated to be about half of the total baryonic matter,**

$H_0 := 73 \frac{km}{s} \cdot (Mpc)^{-1}$ $\quad M_{Baryon} := 2 \cdot M_{tot\_stars}$ $\quad M_{Baryon} = 7.956 \times 10^{53}\,kg$

Estimate the Density of Matter, Mass, and Number of Atoms in the Universe

The critical density is that combination of matter and energy that brings the universe coasting to a stop at time infinity. Einstein's equations lead to the following expression for the critical density (ρ_{crit}). **A flat universe implies $\rho_{crit} = 1$**.

Equivalent to 10 Hydrogen atoms per m³

$$\rho_c := 3 \cdot \frac{H_0^2}{8\pi \cdot G} \qquad \rho_c = 1.002 \frac{kg}{m^3} \cdot 10^{-26}$$

Estimates Based on Observable Volume of Universe Give Unreasonable Results

Radius Universe, r_{Univ} $\quad r_{univ} := 13 \cdot 10^9 \cdot light\_year = 1.23 \times 10^{26}\,m$ $\quad V_{univ} := \frac{4}{3}\pi \cdot r_{univ}^3$

Mass of Observable Universe: $Mass_{Univ} := V_{univ} \cdot \rho_c$ $\quad Mass_{Univ} = 7.808 \times 10^{52}\,kg$ $\quad V_{univ} = 7.792 \times 10^{81}\,L$

Mass Observable (Galaxies) Universe: $\rho_{galax} := 3 \cdot 10^{-28} \frac{kg}{m^3}$ $\quad M_{galax} := \rho_{galax} \cdot V_{univ} = 2 \times 10^{51}\,kg$

Mass of Hydrogen:

$m_H := 1.67 \cdot 10^{-27}\,kg$ $\quad Number_{atoms} := \frac{Mass_{Univ}}{m_H}$ $\quad Number_{atoms} = 4.675 \times 10^{79}$

Fred Hoyle's Estimate

$M_{FH} := \frac{c^3}{2G \cdot H_0}$ $\quad M_{FH} = 8.528 \times 10^{52}\,kg$

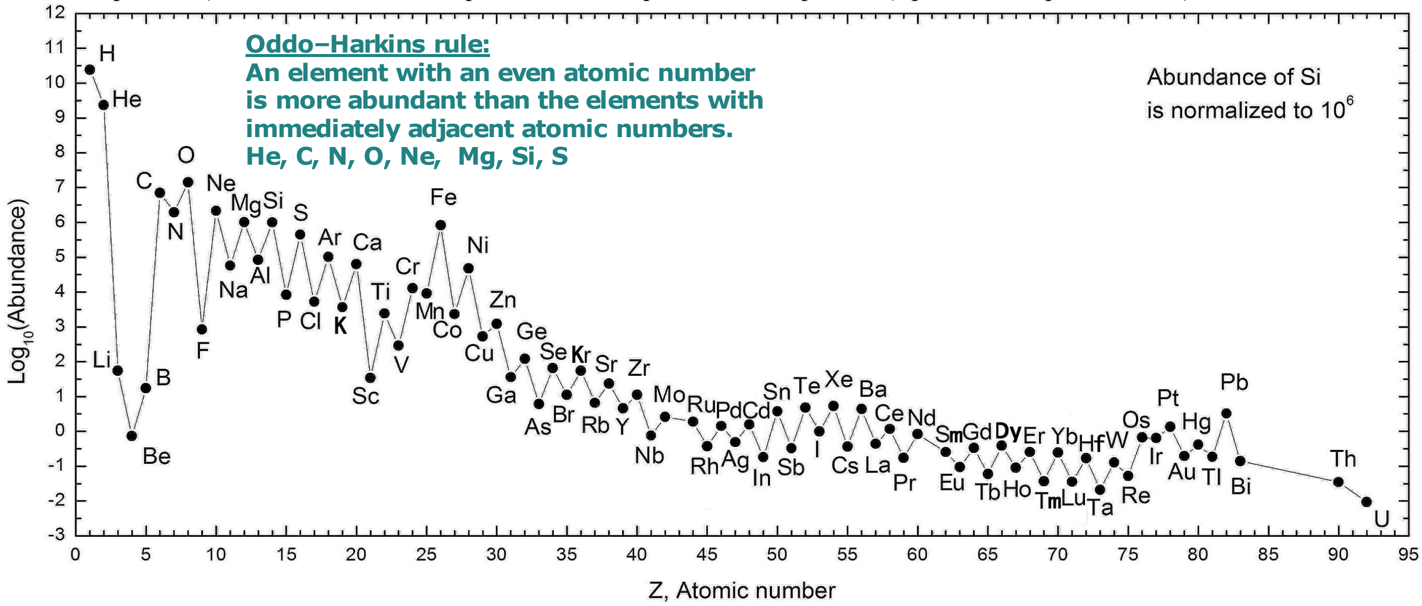
Mass from Observable Radius Fails Sanity Check

$\frac{M_{Baryon}}{Mass_{Univ}} = 10.19$ $\quad \frac{\rho_{Baryon}}{\rho_c} = 2.994 \cdot \%$

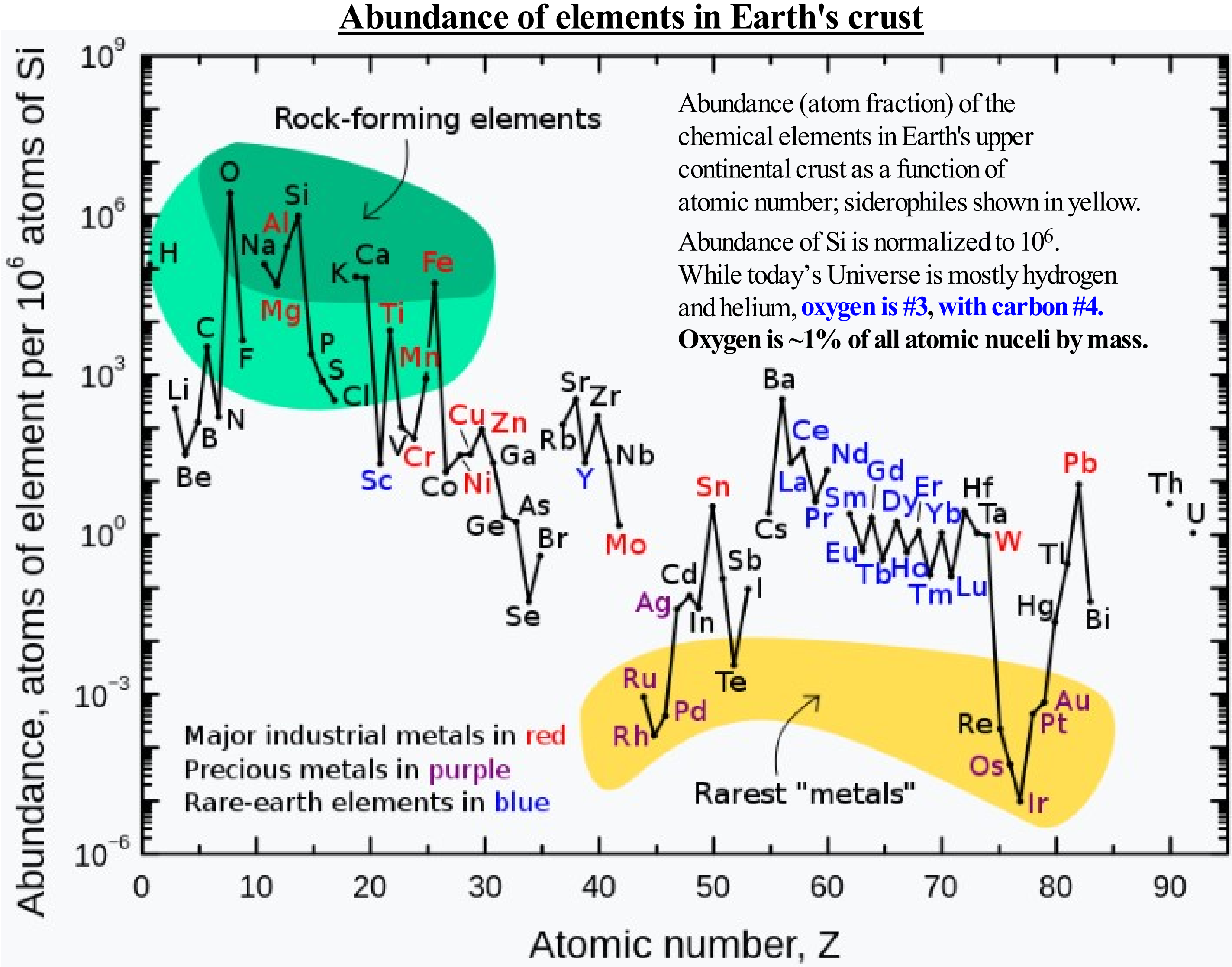
Measuring Age of Universe from Abundance of Elements in Solar System

Nucleocosmochronology

Can use the radioactive decay of elements to age date the oldest stars in the Galaxy. Has been done with the half life of thorium 232 (half life of 14 giga years) and uranium 238 (half life of 4.5 giga years) and other elements. Measuring the ratio of various elements provides an estimate of the age of the universe given theoretical predictions of the initial abundance ratio This is difficult because thorium and uranium have weak spectral lines so this can only be done with enhanced thorium and uranium, (requires large surveys for metal poor stars) and unknown theoretical predictions for the production of R-process, (rapid neutron capture elements).



Abundance of elements in Earth's crust



Graphs of abundance against atomic number can reveal **patterns relating abundance to stellar nucleosynthesis** and geo- chemistry. The alternation of abundance between even and odd atomic number is known as the Oddo–Harkins rule. The rarest elements in the crust are not the heaviest, but are rather the siderophile elements (iron-loving) in the Golds- chmidt classification of elements. These have been depleted by being relocated deeper into the Earth's core; their abundance in meteoroids is higher. Tellurium and selenium are concentrated as sulfides in the core and have also been depleted by preaccretional sorting in the nebula that caused them to form volatile hydrogen selenide and hydrogen telluride.

There are 92 elements. All but the two of them are extremely anomalous, in terms of what we see in the crust of the earth, relative to what we see in Rocky material elsewhere in the universe. The two that are normative are manganese and iron. Everything else is anomalous, and in some cases, extremely anomalous. So for example, the crust of the earth is 630 times as much thorium 340 times as much uranium as what we see in Rocky material in the rest of the universe. And as thanks for that super abundance of uranium and thorium, our planet a long lasting hot core. And that hot liquid iron core, being circulated, has enabled our planet to have a strong magnetosphere and developing us that allows us to be protected from deadly solar and cosmic radiation. It also prevented the atmosphere and the oceans of the Earth from being sputtered away by the particle radiation from the sun.apacity. So we got 60 times less sulfur, that's what enables us to grow food, you're not going to grow any food or crops on Mars, because there's way too much sulfur there. But you can on the earth, so we're deficient by a factor of 60 times in sulfur. But were abundant by a factor of 60 times in aluminum, 90 times in titanium, which enables us to construct aircraft that can fly all over the world. These are light metals that have very high strength. And so we have in a very anomalous high abundance of these valuable elements. And they're 22 elements we see in the periodic table, that are what we call vital poisons. If they exist in the crust of the earth, at too high of an abundance level, it'll kill us, but too low of an abundant level, it will also kill us.

So we have to have just the right amount of molybdenum, and the crust of the earth, just the right amount of iron, just the right amount of arsenic. There's actually proteins in your body that need arsenic, but you only need a very, very tiny amount, and you get above that tiny amount, the arsenic will kill you. And it has to be at just the right level. And so all 22 of these vital poisons are extremely anomalous, and their abundance level here on planet Earth. And we don't see it anywhere else in the universe. So it really does look like somebody engineered it to get it just right. And astronomers again have discovered how this happened. How the early solar system formed in a gigantic cluster of about 20,000 stars that existed much closer to the center of the galaxy than the solar system exists today. And in that dense cluster of stars, the early emerging solar system got exposed to three different kinds of supernova eruption events. It got exposed to neutron stars merging together to make black holes, where the supernova and neutron star merging events happen at exactly the right time, and the right distance from the earth so that the earth was not destroyed. But on the other hand, got sufficiently enriched in all these elements and sufficiently depleted and elements be a problem. And then when all that enrichment depletion was accomplished, we got kicked out of the birth cluster and driven to a distance twice as far away from the center of the galaxy, what kicked us out, it was a gravitational slingshot, where our solar system was interfacing with four or five very massive stars that slung us out of the birth cluster. And then when we got to the ideal place for advanced life, we again engage another four or five, six massive stars that halted our movement. And so we were born in the most dangerous part of our galaxy. And we ended up in the safest part of our galaxy, but only after we got in rich. Now, it's also true that our planet **Earth is anomalous**, compared to all the other planets, and asteroids we see in in our solar system. And that's because our Earth formed, in a way incredibly different from the other planets, the other planets formed by gravitational accretion. And our solar system began with 10 planets, not eight, five gas giants and five rocky planets. Two of those rocky planets, so proto Earth and Thea collided with one another, when the Earth had oceans 1000s of kilometers deep, that very deep ocean cushion the collision, so the earth was not destroyed. In fact, what happened, most of the mass of thea got absorbed into the earth. So the earth became bigger, more massive and denser. There is a debris cloud around the new forming Earth, that condensed to make the moon. And so we have this relatively small planet, orbited by a gigantic moon that stabilizes the tilt of a rotation axis. It ensured that at the just right time for human beings, we have a rotation rate slowed down to 24 hours. And that this gas giant planet, it got kicked out by a gravitational interaction with Jupiter and Saturn. And that gravitational interaction basically slimmed down Mars from being a planet about twice the mass of Earth, down to a planet. That was only one night the mass of the Earth. This was called the Smar small Mars problem. It took 20 years for astronomers to determine how did Mars get to be so small, but we now recognize if it wasn't for that transformation of Mars, there'd be no possibility for advanced life to exist on planet Earth.

ESTIMATIONS OF TOTAL MASS AND ENERGY OF THE OBSERVABLE UNIVERSE

Dimitar Valev, Physics International 5 (1): 15-20, 2014

To determine gravitational and kinetic energy of the observable universe, information of the size and total mass of the universe are needed. There are different estimations of the mass of the observable universe covering very large interval from 3×10^{50} kg (Hopkins, 1980) to 1.6×10^{60} kg (Nielsen, 1997). Also the estimations of the size (radius) of the universe are from 10 Glyr (Hilgevoord, 1994) to more than of 78 Glyr (Cornish et al., 2004).

Estimate Mass of Universe by Dimensional Analysis

The fundamental parameters as the gravitational constant G, speed of the light c and the Hubble constant $H \approx 70\ \text{km s}^{-1}\ \text{Mp}_{s-1}$ (Mould et al., 2000) determine the global properties of the universe. Therefore, by means of these parameters, **a mass dimension** quantity m_{dim} related to the universe could be constructed:

$$m_{dim} = kc^{\alpha} G^{\beta} H_0^{\gamma}$$

where, k is a dimensionless parameter of the order of magnitude of a unit and α, β and γ are unknown exponents which have been found by means of analysis. Taking into account the dimensions of the quantities in the mx Equation we obtain the system of linear equations for unknown exponents Equations:

We use the determinant Δ of the system for the above mx Equation to find the parameters by Kramer's formula.

$$\alpha + 3\beta = 0 - \alpha - 2\beta - \gamma = 0 - \beta = 1 \qquad \Delta = \begin{vmatrix} 1 & 3 & 0 \\ -1 & -2 & -1 \\ 0 & -1 & 0 \end{vmatrix} = -1 \qquad \alpha = \frac{\Delta_1}{\Delta} = 3\ \beta = \frac{\Delta_2}{\Delta} = -1\ \gamma = \frac{\Delta_3}{\Delta} = -1$$

Check Exponent Values

This result gives the correct solution for exponent α, β, λ

$$\alpha := 3 \qquad \beta := -1 \qquad \gamma := -1$$

$$\alpha + 3\beta = 0 \qquad -\alpha - 2\beta - \gamma = 0 \qquad -\beta = 1$$

Compare this to the above estimate

Theoretical Estimate of the Maximum Number of Stars in Universe

Mass from Dimensional Analysis

$$m_{dim} = kc^{\alpha} G^{\beta} H_0^{\gamma} \qquad m_{dim} := \frac{c^3}{G \cdot H_0} \qquad m_{dim} = 1.706 \times 10^{53}\ kg$$

Mass from Critical Density, ρ_c

$$Mass_{Univ} = 7.808 \times 10^{52}\ kg$$

WMAP Estimate: $Pecent_{baryonic} := 0.046$

$$MassUniv_{baryonic} := Pecent_{baryonic} Mass_{Univ}$$

$$MassUniv_{baryonic} = 3.592 \times 10^{51}\ kg$$

The most common type of star turns out to be one with about 0.25 solar mass.

$$M_{typical} := 0.25 \cdot M_{\odot}$$

$$Num_{stars} := \frac{MassUniv_{baryonic}}{M_{typical}}$$

$$Num_{stars} = 7.223 \times 10^{21}$$