TRICKS of the NATURE

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Ten short stories about accidental equalities or cancellations which lead to surprises as well as to useful applications.

Inspired by

R.Peierls, *Surprises in Theoretical Physics*, Princeton University Press1979.

R.Peierls, *More Surprises in Theoretical Physics*, Princeton University Press1991.

V.F.Weisskopf, *Search for Simplicity,* Am.J.Phys **53** (1985) 19,109,206,304,399,522,618,814,940,1140; **54** (1986)13,110.

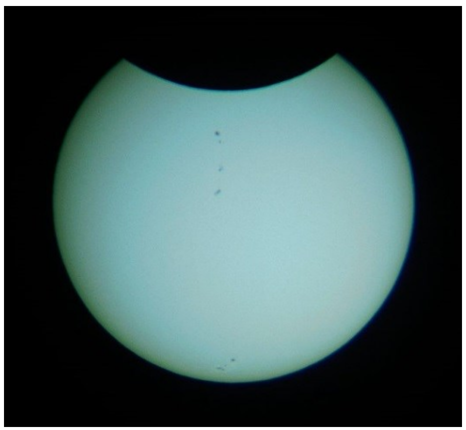
Jo Hermans, *Physics in Daily Life,* EDP Sciences 2012.

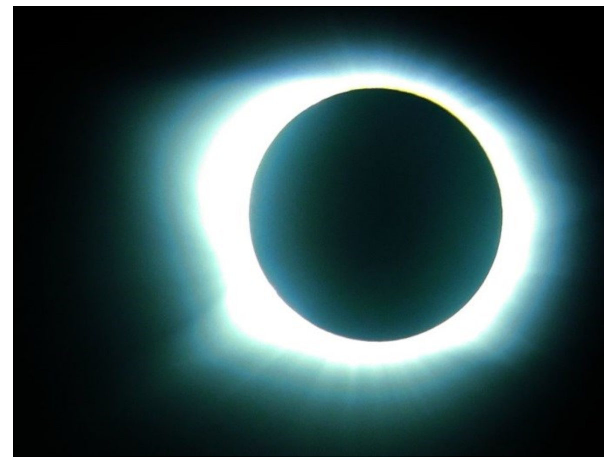
1. TOTAL SOLAR ECLIPSE

The apparent sizes of SUN and MOON are more or less the same. Therefore we see occasionaly a total solar eclipse or an anular eclipse (when the moon is far or the Sun is near).

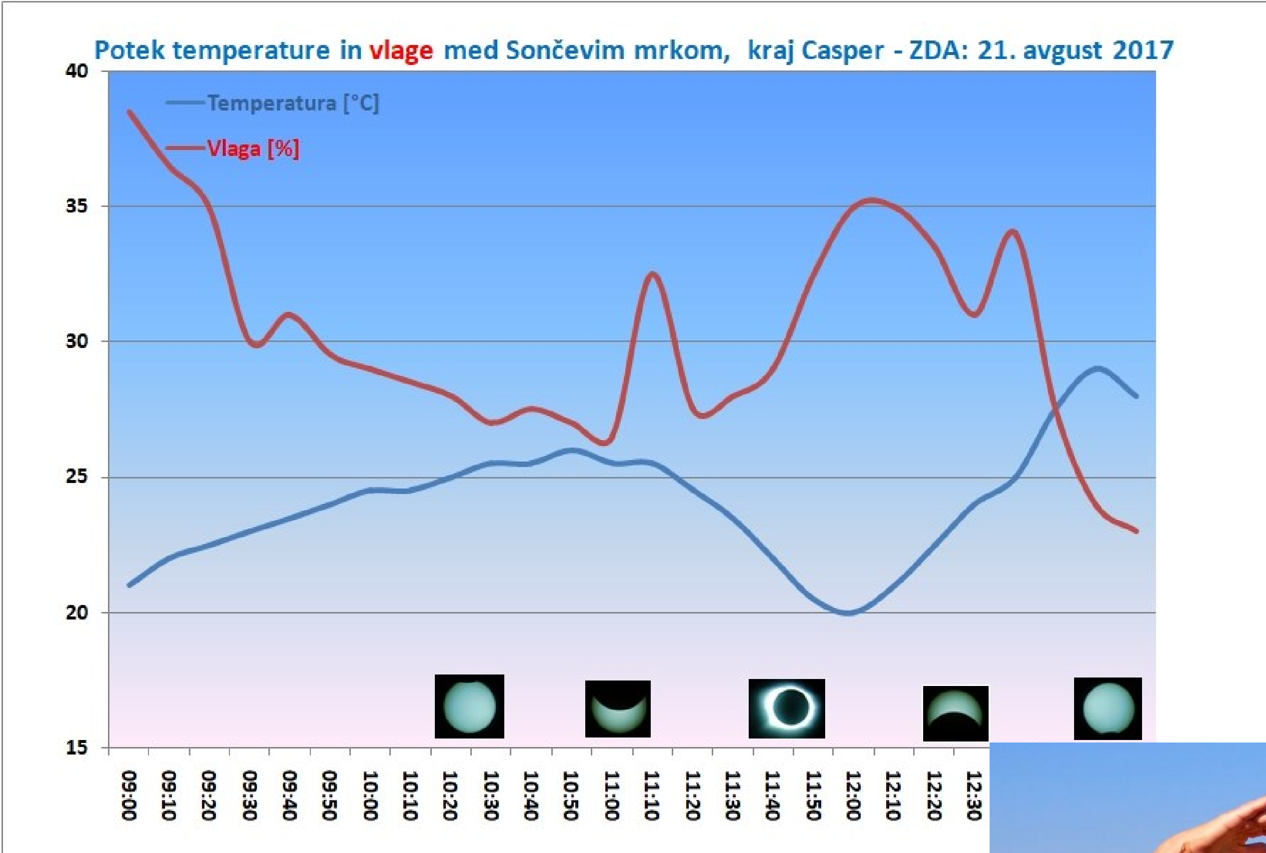
$\alpha_{sun} = 2r_{sun}/R_{sun} = 1.4\times10^{9}m/150\times10^{9}m \approx 0.01 \approx 30'$

$\alpha_{moon} = 2r_{moon}/R_{moon} = 3.5\times10^{6}m/380\times10^{6}m \approx 0.01 \approx 30'$





Casper, Wyoming,USA,
August 21, 2017
10:22 – 11:42:39
– 11:45:09 – 13:09
(photo: Zorko Vičar)



Our enthusiastic „Solar expedition“ 2017 counted 16 participants.

The temperature dropped by 6^0, then it rose by 9^0 (Zorko Vičar)

We visited several national parks in the Western USA

Rocky Mountains NP
Kolorado

Yellowstone NP
Wyoming/
Montana / Idaho

Grand Teton NP
Wyoming

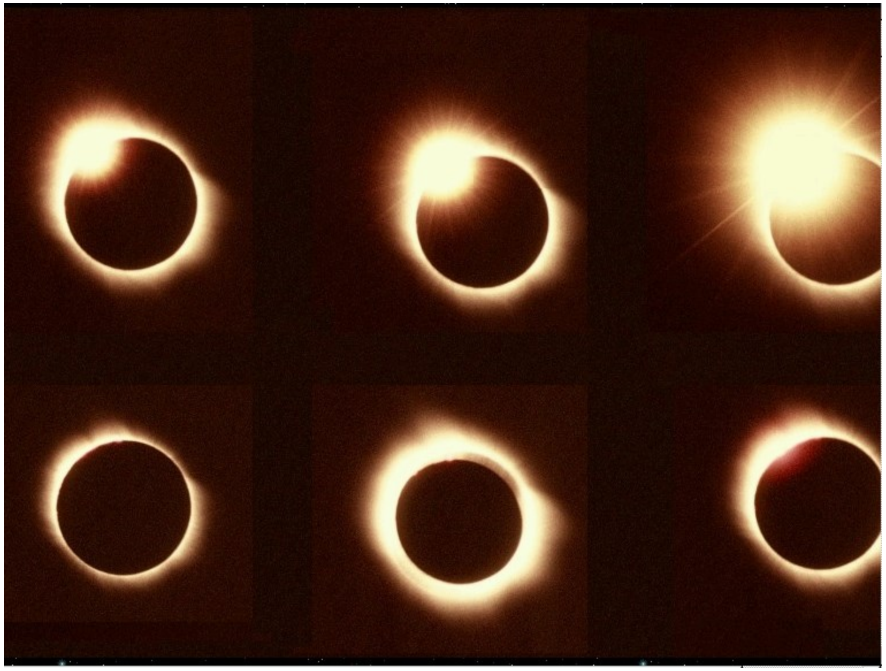
Great Salt Lake
Utah

Zion NP
Utah

Bryce Canyon NP
Utah

Horseshue Bend
(Colorado river)
Arizona

Grand Canyon
Arizona



TOTAL SOLAR ECLIPSE IN TURKEY 29.3.2006

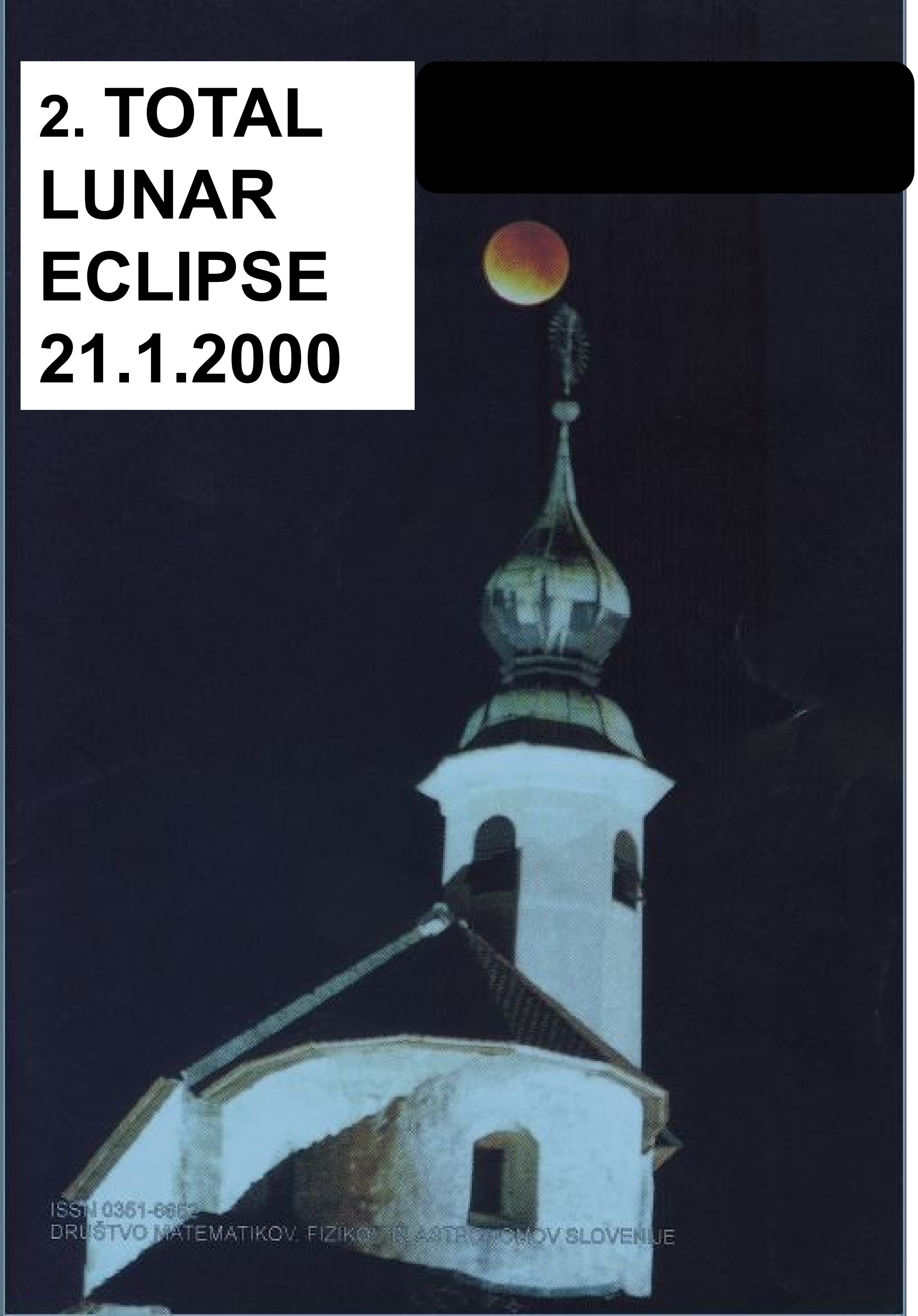
PHOTO: Zorko Vičar and his team

Vladimir Brezar: Solar eclipse in Antalya, Turkey 2006

Ivan Generalić: Pomrčenje sunca (1961)

2. TOTAL LUNAR ECLIPSE 21.1.2000

[redacted]



The brilliance of the moon

Was estimated by comparison with the church

j_{in} = 10 lx

(1000 cd reflector at 10 m).

Albedo:

a(wall) = 0.6, a(roof) = 0.04

j_{out}(wall) = 6 lx

j_{out}(roof) = 0.4 lx

j_{out}(moon) = inbetween

Surprise: Why is the eclipsed Moon so brilliant?

Answer: The air layer around the illuminated ring facing the Moon acts as a ring lense and the Moon happens to be near the focus.

For a spherical lense $f = R/2(n-1)$. With $R(earth) = 6400$ km and $n = 1{,}0003$ we get $f = 10^7$ km. TOO MUCH!

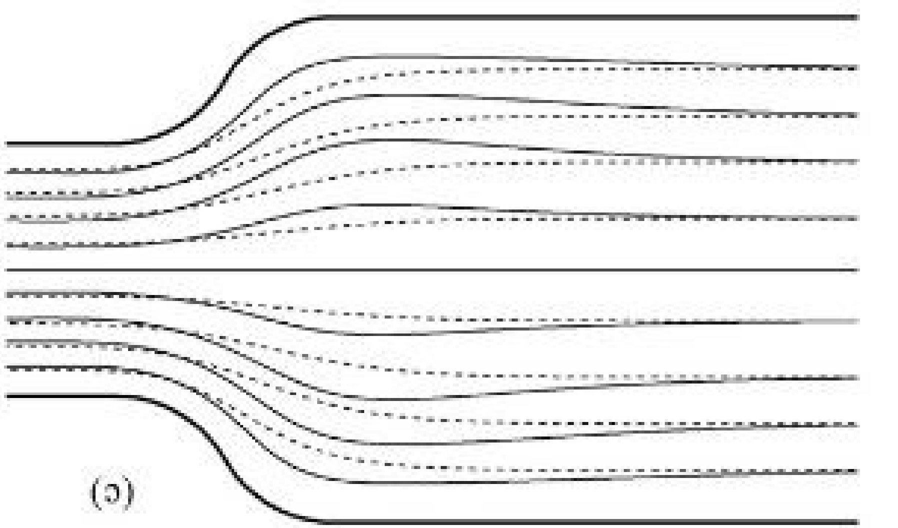
For a ring lense $f = \sqrt{Rh/2\pi}/(n-1)$.
$h = 7.7$ km is the effective thickness of Earth atmosphere (exponential decrease assumed). We get $f = 300\,000$ km. FINE!

Illumination of the Moon

Sun illuminates Earth with $j_0 = 100\,000$ lx.
The incoming light on the ring is distributed around the focus to an area of Earth cross section or more (an estimate from drawing the rays).
The Moon gets
$j_{in} < j_0 \times (2\pi\, Rh / \pi R^2) = j_0\, (2h/R) = 240$ lx.
The Moon shines (albedo = 0,08)
$J_{out} < 20$ lx (or less, depending on the weather).

3. TROUT IN A DIVERGENT CURRENT

I was surprised to see a trout swimming at a fixed point in a rapid river. The explanation is easy: The trout was swimming at a constant speed, the same but oposite as the water. If she came forward, she was carried back by the faster water. If she stayed backward, She overtook the slower water. Note that we are also used to walk or swim at a constant speed.



4. ENERGY SOURCE OXYGEN

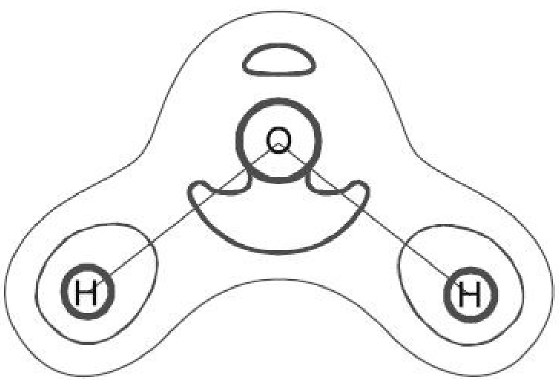
The oxygen double bond (O=O) is a covalent bond. The bond energy is only as large as a single bond energy for light atoms in the (2s, 2p) shells and in the hydrogen molecule.

H_2	bonds=1	ΔE/bond = 106 kcal/mol = 4.6 eV
-C-C-	bonds=1	ΔE/bond = 100 kcal/mol = 4.3 eV
CH_4	bonds=4	ΔE/bond = 98 kcal/mol = 4.3 eV
H_2O	bonds=2	ΔE/bond = 96 kcal/mol = 4.2 eV
CO_2	bonds=4	ΔE/bond = 106 kcal/mol = 4.6 eV
O_2	bonds=2	ΔE/bond = 59 kcal/mol = 2.4 eV

One speaks of fossil fuel energy sources and means coal, gas and oil. The energy is, however, stored in atmospheric oxygen! Example: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. The number of covalent bonds (8) remains constant, as the four weak oxygen bonds are replaced by four stronger ones. ΔE = 190 kcal ≈ 4×2 eV. Photosynthesis, which separates oxygen from carbon, has stored the energy in the weak bond in oxygen.

5. DIRECTIONALITY OF THE COVALENT BOND IN p SHELL

H_2O	104.5^0	NH_3	106.7^0	CH_4	109.5^0
H_2S	92.2^0	PH_3	93.3^0	SiH_4	109.5^0
H_2Se	91.0^0	AsH_3	91.8^0	GeH_4	109.5^0
H_2Te	89.5^0	SbH_3	91.3^0	SnH_4	109.5^0



Water molecule.

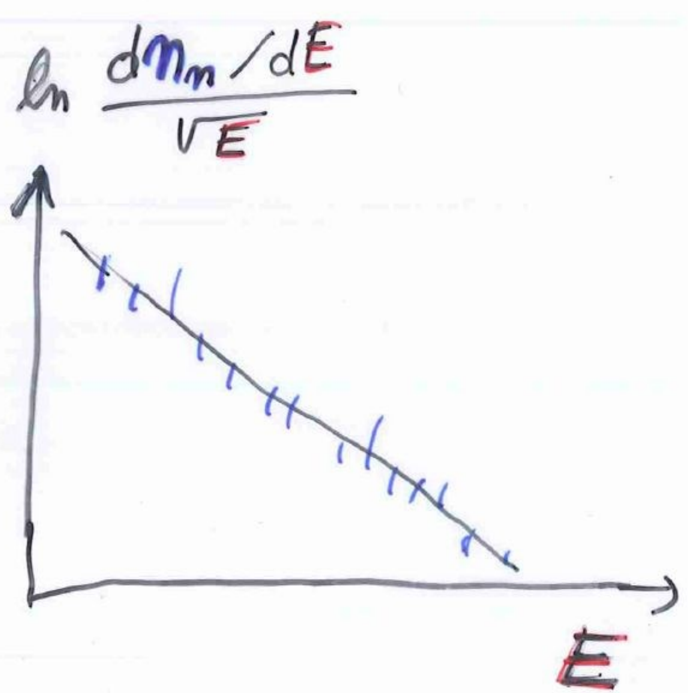
Two orthogonal 2p orbitals are maximally correlated at an angle of 90^0. A superposition of 2s-2p may be at any angle between 90^0 and 120^0. Admixture of 2s is less favoured by electrons but more by repulsion of ions.

1. **Large electric dipole moment ($\mu_e = 0.068\ e\ a_0$) → High refraction**
2. **Large electric dipole moment → Good solvent**
3. **Forms rings → Ice is lighter than water**
4. **Forms rings → Large specific heat (9k instead of 6×k/2 = 3k)**

6. EVAPORATION OF NEUTRONS FROM FISSION PRODUCTS

During the fission of uranium sufficient number of neutrons for the chain reaction is evaporated. The temperature of the two fission fragments is just high enough to evaporate 2 - 3 neutrons.

$$^{235}U + n \rightarrow {}^{236}U^* \rightarrow (A_1^* \rightarrow A_1 + n + \gamma) + (A_2^* \rightarrow A_2 + n + \gamma + \gamma)$$



Slope = „thermometer“

$dn_n/dE = \sqrt{E}\,\exp(-E/kT)$

$kT = 1.3$ MeV

Richardson: $n_n = (m_n/2\pi^2\hbar^3)(kT)^2 \exp(-W_i/kT)\times S\times t$

$W_i = 7.5$ MeV,
S= surface area of both nuclei, t=lifetime

Stefan-Boltzmann: $E_\gamma = \sigma T^4 \times S\times t$

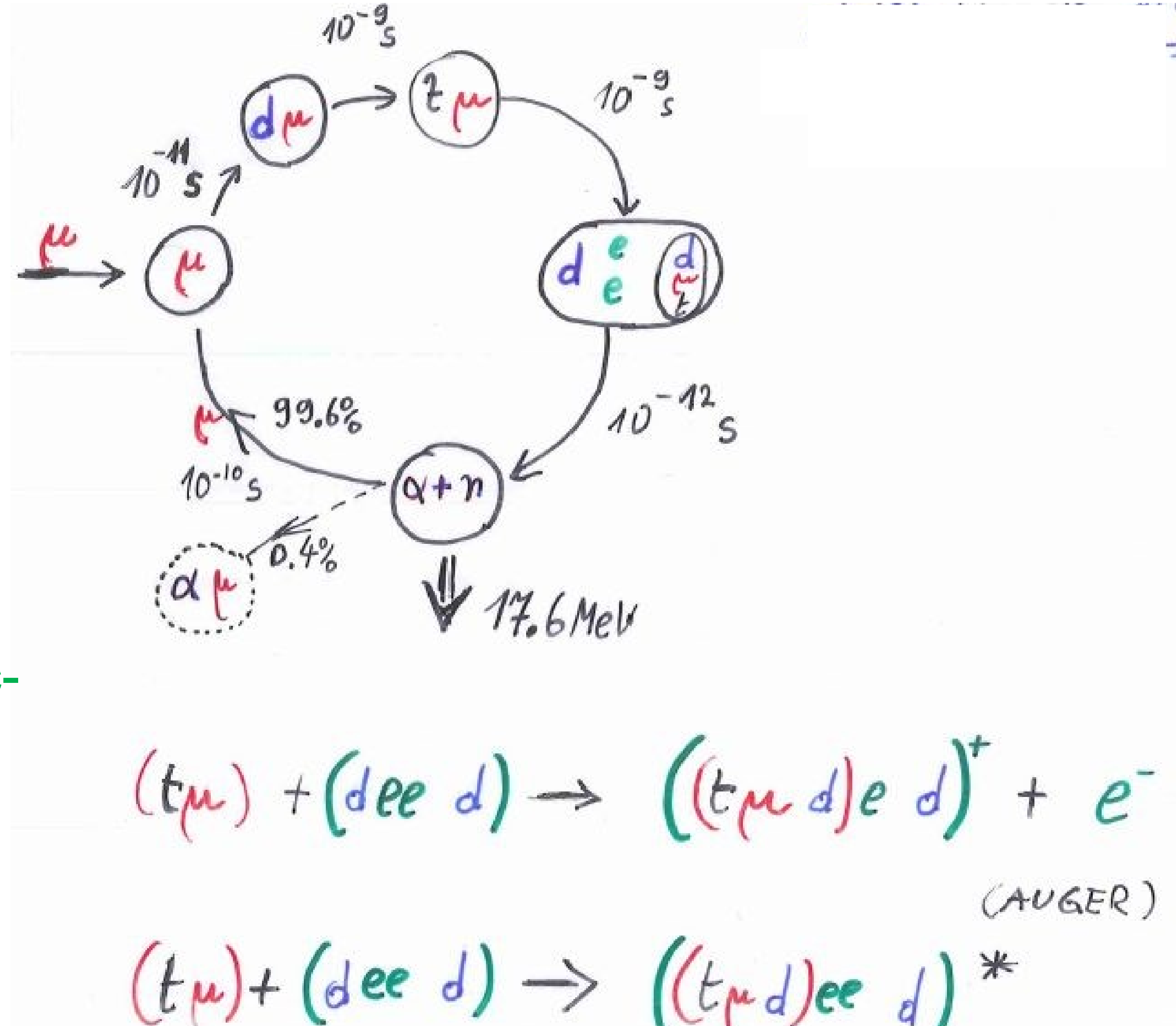
$(n_n \times 3kT/2) / E_\gamma \approx 1$

Experiment: E_n ($= n_n \times 3kT/2$) = 5 MeV, [n_n =2,6]
E_γ = 6 MeV

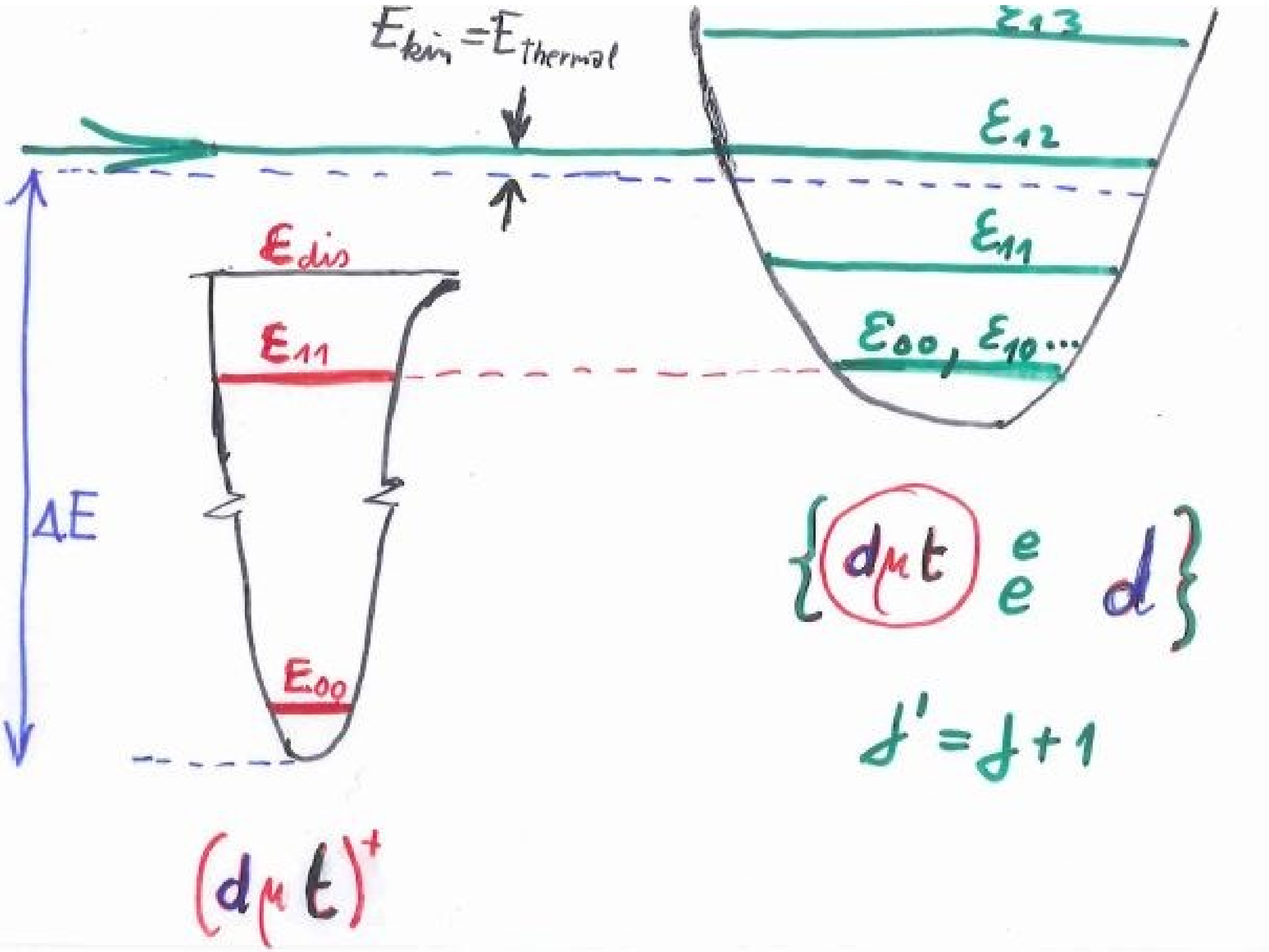
(These values are consistent with the above formulas and nuclear model assumptions.)

7. MUON CATALYSED FUSION

Muons can catalyse over 150 fusions of deuteron and triton into helium, because the energy balance for the resonant formation of a combined muonic-electronic molecule can be adjusted to meV precision at 0,3 keV.



(resonanca)



$$E_{t\mu} + E_{dee\,d} + E_{kin} = E_{((d\mu t)ee\,d)} + \varepsilon_{Jv} + \varepsilon_{jv}$$

$$\boxed{\Delta E + E_{kin} = \varepsilon_{Jv} + \varepsilon_{jv}}$$

8. THE SYNTHESIS OF CARBON FROM HELIUM IS HELPED BY RESONANCES

The synthesis of carbon and heavier elements in older stars is possible because an excited state in ^{12}C is just at the right place to enhance the resonant synthesis.
„Without this resonance we would not be here!“ (Fred Hoyle)

Middle-aged stars (our Sun): $4\ ^{1}H \rightarrow\ ^{4}He + 2\ e^{+} + 2v$

Old stars ($\rho=10^{9}$ kg/m^{3}, T= 10^{8} K):

$^{4}He + ^{4}He \leftrightarrow ^{8}Be - 0.092$ MeV
$^{8}Be + ^{4}He \leftrightarrow ^{12}C^{*} - 0.288$ MeV
$^{12}C^{*} \rightarrow ^{12}C + 2\gamma + 7.654$ MeV

$\rho = 10^9$ kg/m^3, T= 10^8 K, kT = 8.6 keV, $n_4 = 1.5\times10^{35}$ m^{-3}

$\mu_4 + \mu_4 = \mu_8 \quad +\Delta E_8$; $\quad n_8 / n_4 = 6.6\times10^{-9}$

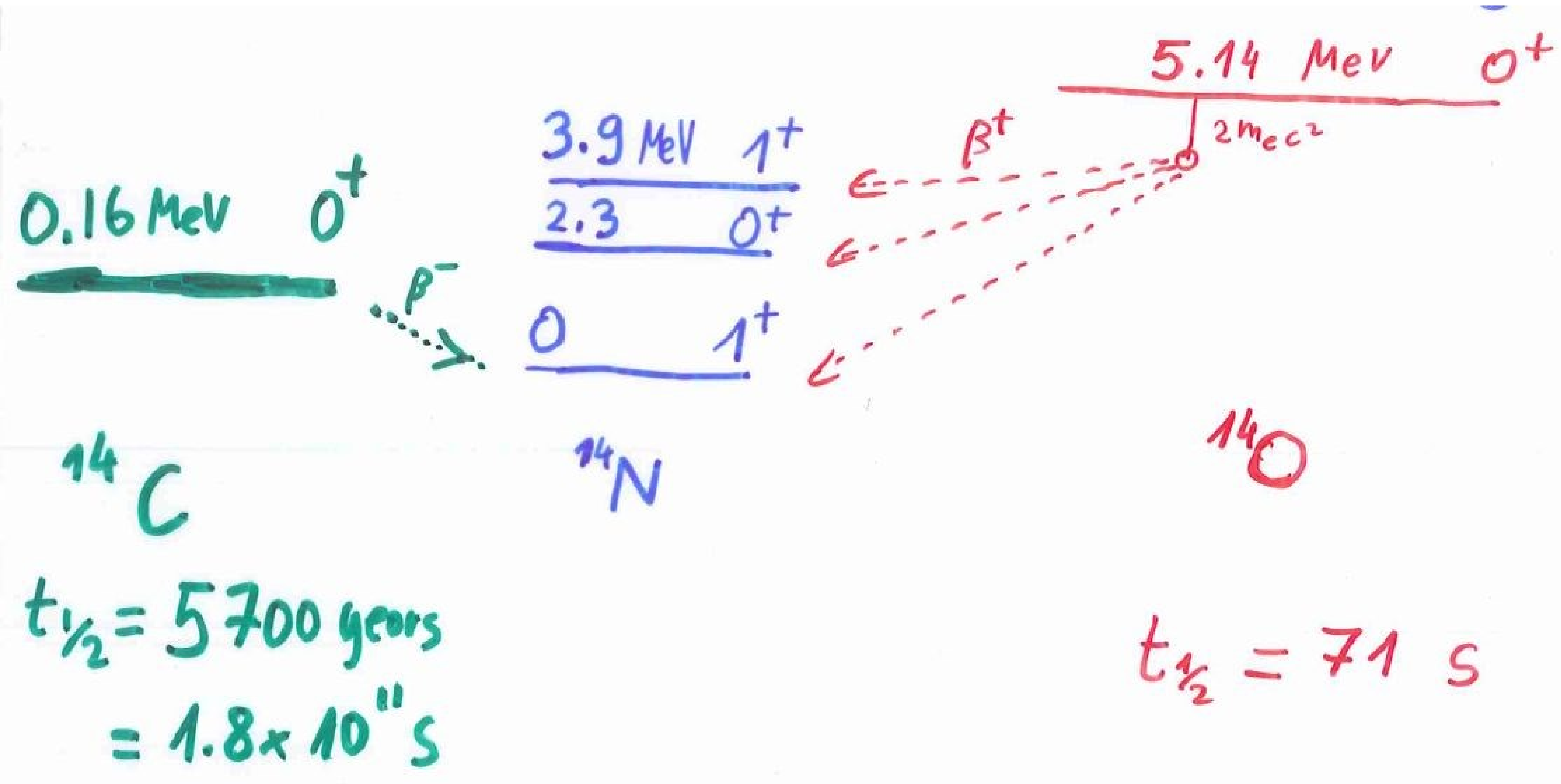
$\mu_8 + \mu_4 = \mu^*_{12} + \Delta E_{12}$; $\quad n^*_{12} / n_4 = 3.7\times10^{-27}$

$d\,n_{12} / d\,t = n^*_{12}\, w$, $\quad w = 5.6\times10^{12}$ s^{-1}

$(d\,n_{12} / d\,t) / n_4 = 2.1\times10^{-14}$ s^{-1} = $(1.5\times10^6$ years$)^{-1}$

9. THE ^{14}C NUCLEUS HAS A NINE ORDERS OF MAGNITUDE LONGER HALFLIFE THAN THE MIRROR NUCLEUS ^{14}O

→ PLEASURE FOR ARCHEOLOGISTS!



The ^{14}C and ^{14}O nuclei can decay into the ground state of ^{14}N through everal intermediate states. The accidental destructive interference is almost perfect in ^{14}C, but not in ^{14}O. Moreover, the ^{14}O decay has a larger phase space, and can also decay into excited states of ^{14}N.

The beta-decay matrix element in $^{14}C \longrightarrow {}^{14}N$ is retarded to 0.1% while in $^{14}O \rightarrow {}^{14}N$ it is retaded to 1%.
It misses the „perfect cancellation“ by 1%.
Anyway, 1% is the precision of isospin symmetry

10. THE MASS OF THE STRANGE QUARK IS SUFFICIENT TO PREVENT THE COLLAPSE INTO STRANGE MATTER

The Pauli Principle would favour a nuclear matter composed of several flavours of quarks (for example s quarks in addition to u and d quarks) if s quarks were not sufficiently heavy.

Experimental hint:

There are no ΛΛ= uds+uds bound states;

The $_{\Lambda\Lambda}{}^{6}He$ decays weakly.

Nuclear matter estimate: g=2×2×3=12 (spins, isospins, colours)

$W=(3/5)\,(p_F^2/2m)$, $N = 3n_q$

E/N=3 m +3 W =3 (223+87) MeV=930 MeV

Strange matter estimate: g=2×3×3=18 (spins, flavours, colours)

$m_s - m \approx m_\Lambda - m_N \approx m_\Xi - m_\Lambda \approx 180$ MeV (from experiment)

$E/N = [2\,(223+87\sqrt[3]{12/18}) + 1(403+87\sqrt[3]{12/18}\,(223/403)]$ MeV

= 1043 MeV. **WE ARE SAFE !!!**