1501.03101

$^{26}Al \to {}^{26}Mg$ dating by comparison with stable $^{27}Al/^{24}Mg$

Excess of ^{26}Mg is found from $^{26}Mg/^{27}Mg$

$N_{now} = N_{ini} \cdot e^{-\lambda t}$

$U \to Pb$ $\quad \boxed{N_{U_{ini}} = N_{U_{now}} + N_{Pb_{now}}}$ Closed system

$N_{U_{now}} = (N_{U_{now}} + N_{Pb_{now}}) \cdot e^{-\lambda t}$

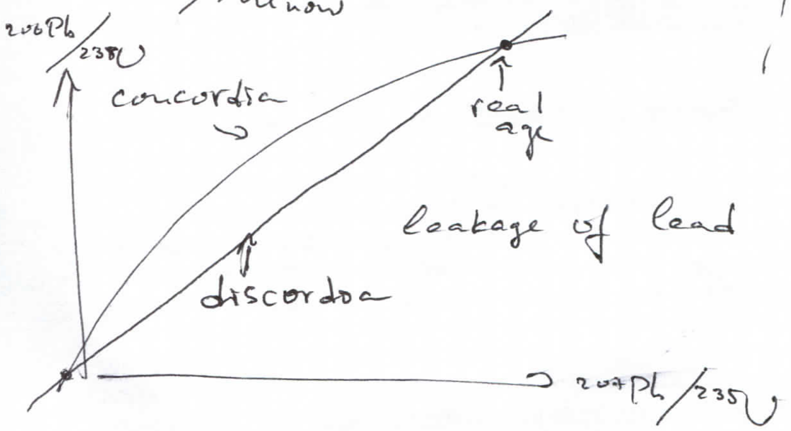
$N_{Pb_{now}} / N_{U_{now}} = e^{\lambda t} - 1$

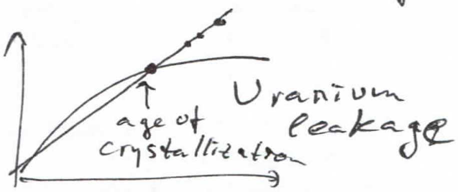
now

$$\frac{^{206}Pb}{^{238}U} = e^{\lambda_{238} t} - 1$$

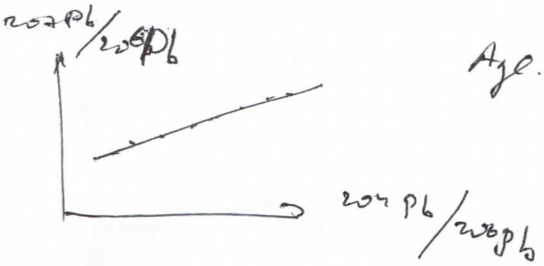
$$\frac{^{207}Pb}{^{235}U} = e^{\lambda_{235} t} - 1$$

concordante ages





No Uranium in CAIs. => Pb-Pb.



It is important, when the studied sample became isolated (cold, etc.)

The system might be closed (no atom exchange with surroundings)
Immediate surroundings can be poor in the radioactive element.

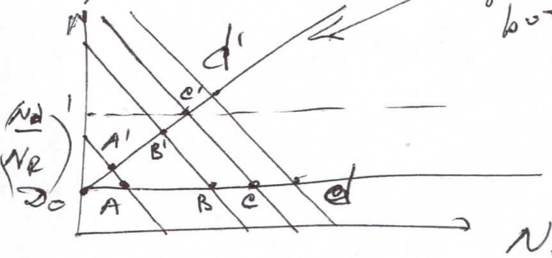
1005. 4147

$e^x = 1 + x + \frac{x^2}{2!} + \ldots$

$e^{\lambda t} - 1 \simeq \lambda t$ for $\lambda t \ll 1$

1bis

Isochron: age the same, $N_p^{(0)}$ different but slope λt



N_p/N_R

D_0 – initial value

$D_0 \equiv (N_d/N_R)_0$

After t : $(N_p/N_R)^A_t = (N_p/N_R)^A_0 \cdot e^{-\lambda t}$
(point A)

A, B, C, d – different ~~elements~~ samples (initial values)

Different samples have the same N_d/N_R, but different N_p/N_R (at formation)

A', B', C', d' – measurements

Protosolar cluster (1001.5444)

1. SN.

a) stripping by explosion.

$P_{ram} = (\rho v^2)_{SN} = A_{SN} E_{SN}/r^3$ (parameters) $\qquad P_\odot \simeq \frac{GM_* \Sigma}{r_d^2}$

b) another condition: $\frac{M_{ej} v_{SN}}{4\pi r^2} = \left(\frac{2GM_*}{r_d}\right)^{1/2} \Sigma(r_d)$

a) is more important (!) Fig 6.

$d \sim 0.1\,pc$ – dangerous!

To get enrichment:

$X_j = f_j \frac{M_j}{M_d} \frac{\pi r_d^2}{4\pi d^2}$ $\qquad M_{Fe_{60}} \simeq 10^{-4} M_\odot$

$(2{,}5 \cdot 10^{-5} \div 1.6 \cdot 10^{-4}) M_\odot$

f_j – fraction of material absorbed by the nebula; M_d – solar nebula mass

$d \sim 0.1 \div 0.3\,pc$ for $M_j \sim 10 \div 100 M_\odot$

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2. Stellar UV.

Massive stars are important $\qquad f_m \simeq 0.8 \qquad$ N – number of stars

$$F_{UV} \simeq \frac{f_m N \langle L_{UV}\rangle_*}{4\pi r^2} = \frac{9 f_m N_0 \langle L_{UV}\rangle_*}{16\pi R_0^2}\left(\frac{N}{N_0}\right)^{1-2\alpha}$$

$$r_g = \frac{GM_*}{a_s^2} = \frac{GM_* \langle\mu\rangle}{kT} \simeq 100\,AU \left(\frac{T}{1000K}\right)^{-1}$$

Mass loss from disc due to photoevaporation $\quad \dot{M} \simeq 9 \cdot 10^{-8} \frac{M_\odot}{yr} \left(\frac{\Phi_{EUV}}{10^{49} s^{-1}}\right)^{1/2} \left(\frac{d}{10^{17} cm}\right)^{-1} \left(\frac{r_d}{30 AU}\right)^{3/2}$

Cluster $N = 300$. Sun at $\frac{1}{2}R \Rightarrow F_{EUV} = \frac{\Phi}{4\pi d^2} \simeq 4.3 \cdot 10^{11} \frac{ph}{cm^2 s}$

$\dot{M} \simeq 6{,}8 \cdot 10^{-9} \frac{M_\odot}{yr}$. for $M_d \sim 0.05 M_\odot$ $\tau \simeq 147\,Myr$

For cluster with $N \sim 3000$ it becomes important ($t \simeq 10$ Myr for 30 AU).

Desch (2007) ApJ

Nice model.

Part of solids, f_p, in planetesimals.

J - 5,45 AU   S - 8-9 AU   U - 11-13 AU   N - 13,5-17 AU (Nice)

+ disc 35 $M_\oplus$ (16÷30 AU)

In Jup & Sat heavy elements >> 1,5 % (6 % for Jup.)

Solids in disc: 0,489% - rock
0,571% - water ice
0.33% - methane ice
0.097% - ammonia ice
} ~ 1%

gas / solid ≃ <u>67</u> ÷ 95

$$M_{aug} = M_Z \cdot f_p^{-1} \left(\frac{gas}{solid}\right)$$

U: $M = 14,9\, M_\oplus$. $M_Z \simeq 12,55 \pm 1.55\, M_\oplus$ $M_{aug} = 843 \pm 124\, M_\oplus \times 2\,(f_p/0.5)^{-1}$

N: $M_{aug} = (1032 \pm 91) M_\oplus \times 2\,(f_p/0,5)^{-1}$

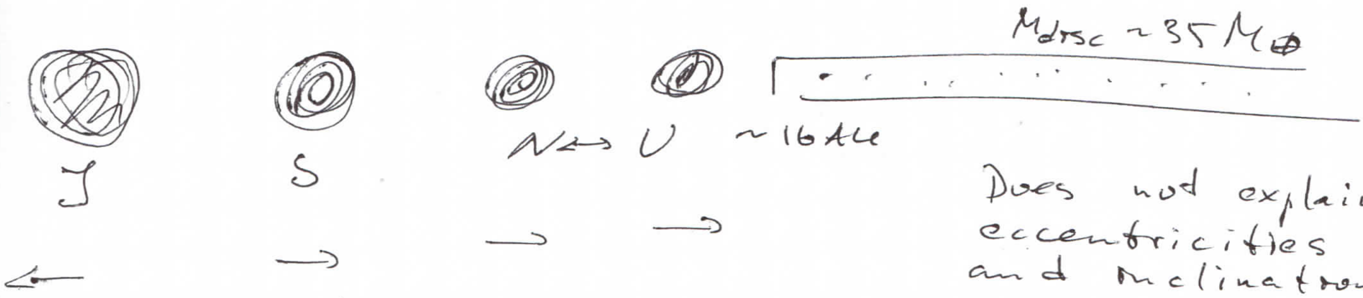
S: $M_{aug} = 1411 \pm 470\, M_\oplus \times 2\,(f_p/0.5)^{-1}$

J: $M_{aug} = 1747 \pm 1075\, M_\oplus \times 2\,(f_p/0.5)^{-1}$

Disc mass (2÷30) AU: $0,06\,(f_p/0.5)^{-1} M_\odot$

Photoevaporation by an external massive star.

Nice model (2005)



Does not explain eccentricities and inclinations.

1 : 2 orbital resonance

Nice II model (2011)

Stirring in the disc of planetesimals.
Interactions with the most eccentric planet (inner ice giant)

Morbidelli, Crida (2007) migration of the Jupiter-Saturn pair.
Migration is stopped (or even reversed) due to a resonance coupling.
(3:2) resonance (or 2:1 / 5:3)

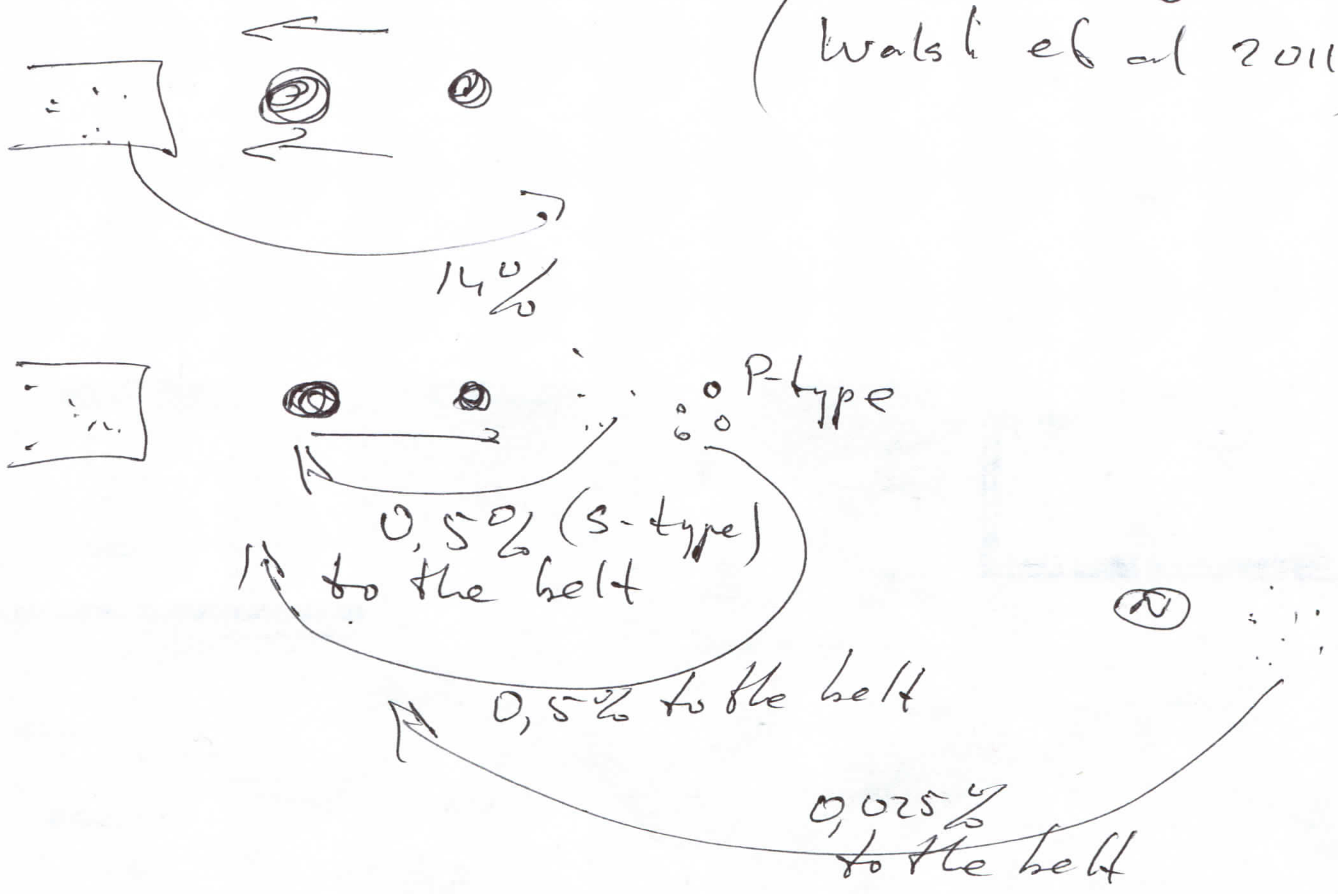
Grand Tack

Problem: light Mars.
Solution: cut planetesimal disc at 1AU.
How: Jupiter! Might come to ~1.5AU.

Disc inside Jupiter 3.7 M⊕ in embryos and planetesimals.

Giant planets migration shepherds small bodies so disc mass inside 1AU doubles reaching 2 M⊕

(Walsh et al 2011)



Grand Tack happened when the gas disc was still present!
