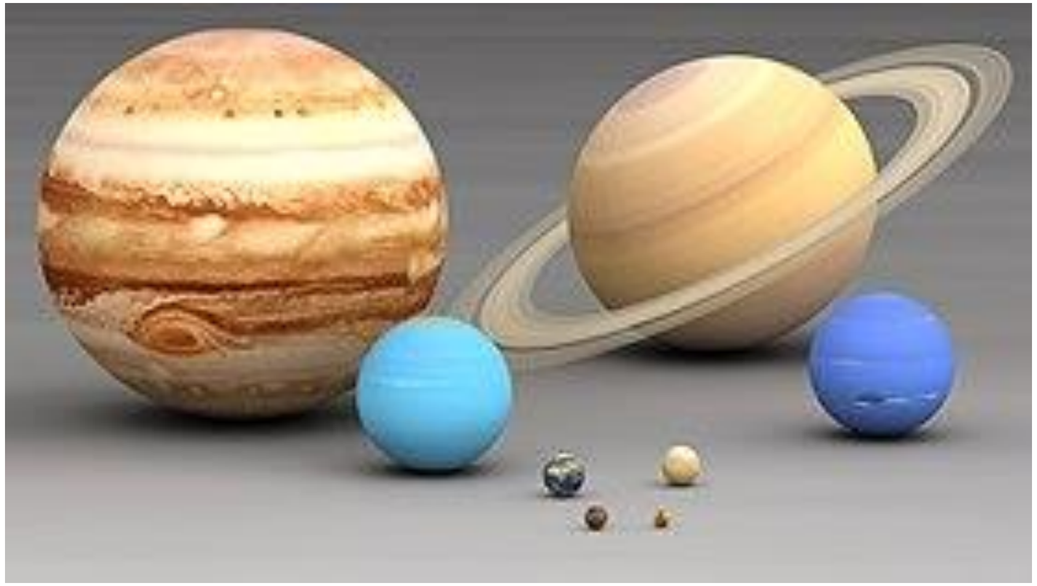
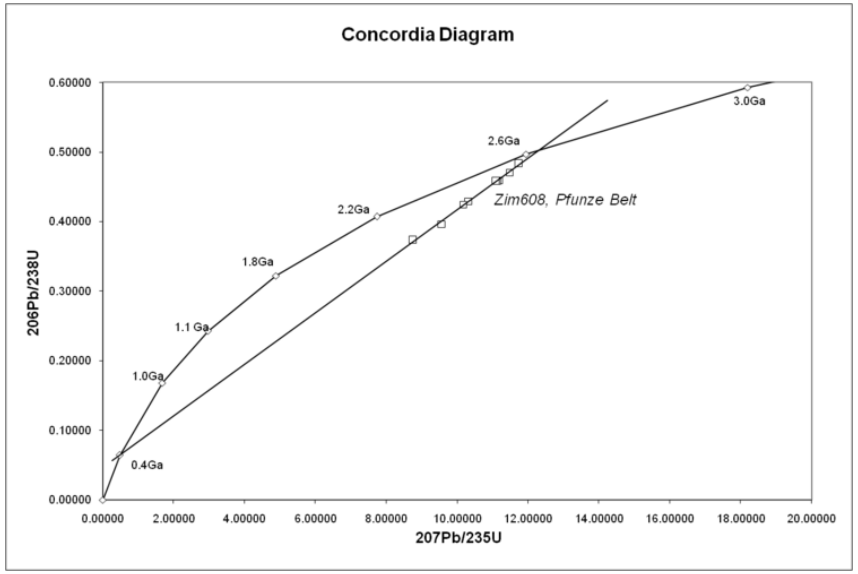
Семинар по Солнечной системе

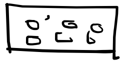
01.12.2020





①

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



U → Pb

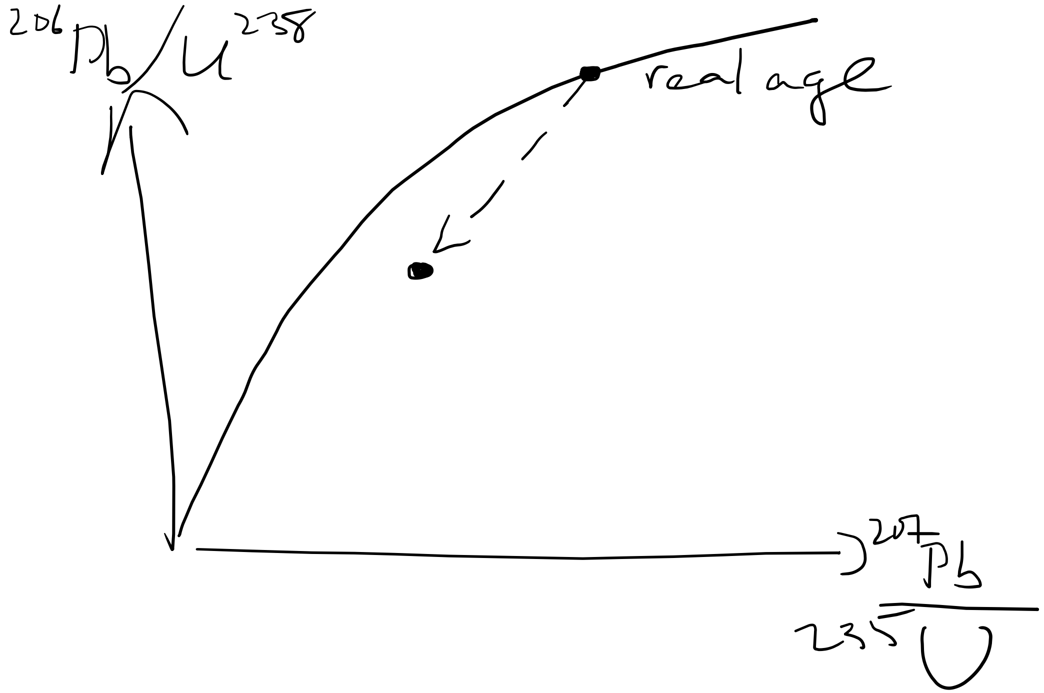
$$N_{U_{ini}} = N_{U_{now}} + N_{Pb_{now}}$$

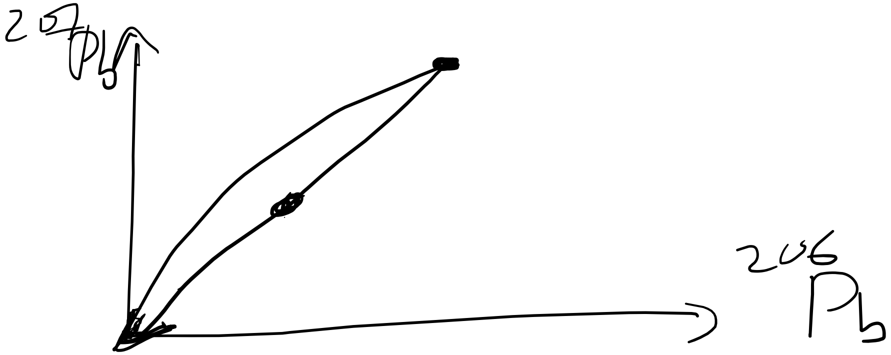
$$N_{U_{now}} = \left(N_{U_{now}} + N_{Pb_{now}}\right) \cdot e^{-\lambda t}$$

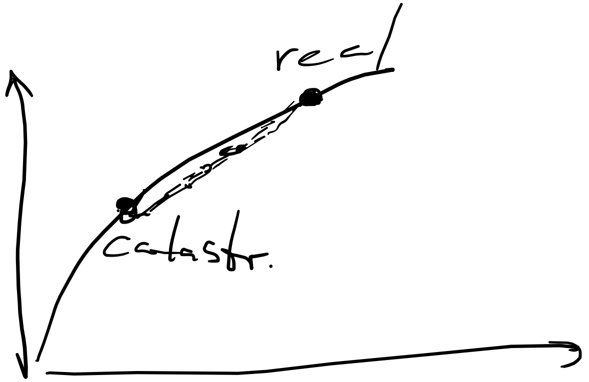
$$\frac{N_{Pb_{now}}}{N_{U_{now}}} = e^{\lambda t} - 1$$

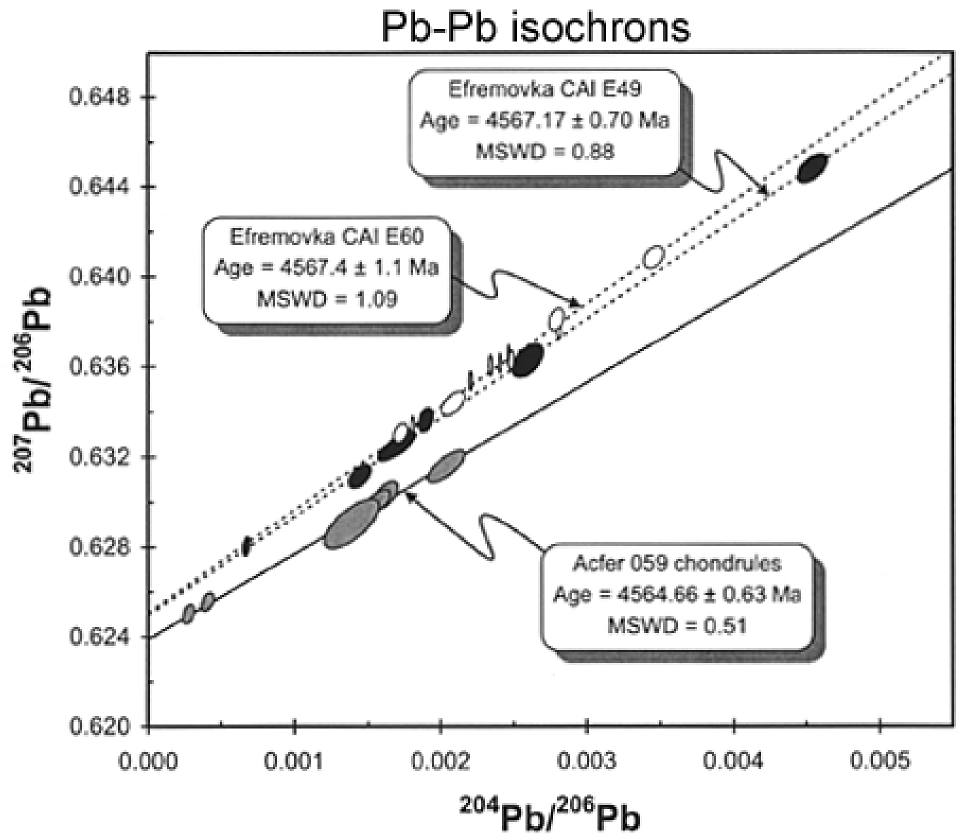
$$\frac{^{206}Pb}{^{238}U} = e^{\lambda_{238} t} - 1$$

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




207Pb
206Pb


real
catastr.

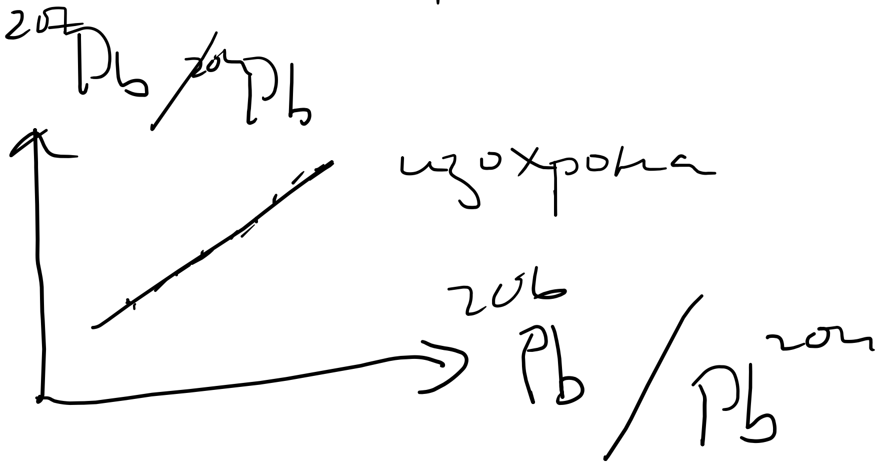


(from Amelin et. al., Science, 2002)

$$\frac{^{207}Pb}{^{206}Pb} = \frac{^{235}U}{^{238}U} \cdot \frac{e^{\lambda_{235}t}-1}{e^{\lambda_{238}t}-1}$$

$1/137,88$

^{204}Pb

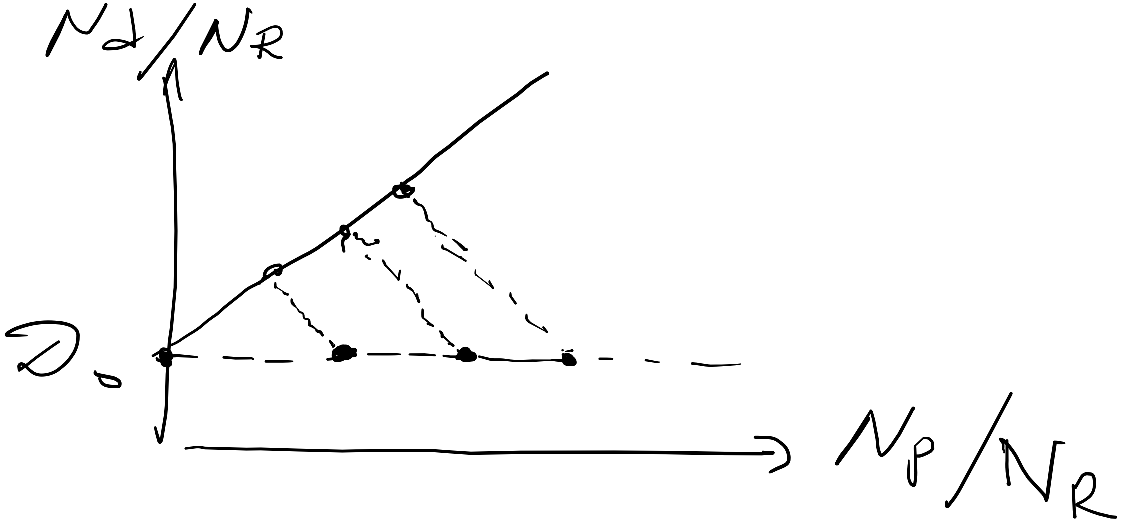


$$R = R_0 + R_{P/D}\left(e^{\lambda t}-1\right). \qquad R = \frac{^{207}Pb}{^{204}Pb} \qquad R_{P/D} = \frac{^{235}U}{^{204}Pb}$$

$\Delta R = R_1 - R_2$ $\quad R_0$ – одинаков $\quad \Delta R_{P/D} = R_{P/D_1} - R_{P/D_2}$

$$\Delta R = \Delta R_{P/D}\left(e^{\lambda t}-1\right) \qquad t = \frac{\ln\left(\Delta R/\Delta R_{P/D}\right)+1}{\lambda}$$

arxiv 1005.4147



P: ^{235}U D: ^{207}Pb

R: ^{204}Pb

D_0 – нач. сод. $D_0 = \left(\frac{N_d}{N_R}\right)_0$

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

$$1 - e^{-\lambda t} = \lambda t$$

$$N_D = N_{D_0} + [N_{P_0} - \underbrace{N_{P_0} \cdot e^{-\lambda t}}_{N_{P\,now}}] = N_{D_0} + N_{P_0}(1 - e^{-\lambda t})$$

1001.5444

Solar System Property	Implication	Fraction
Mass of Sun	$M_* \geq 1 M_\odot$	0.12
Solar Metallicity	$Z \geq Z_\odot$	0.25
Single Star	(not binary)	0.30
Giant Planets	(successfully formed)	0.20
Ordered Planetary Orbits	$N \leq 10^4$	0.67
Supernova Enrichment	$N \geq 10^3$	0.50
Sedna-Producing Encounter	$10^3 \leq N \leq 10^4$	0.16
Sufficient Supernova Ejecta	$d \leq 0.3$ pc	0.14
Solar Nebula Survives Supernova	$d \geq 0.1$ pc	0.95
Supernova Ejecta and Survival	0.1 pc $\leq d \leq 0.3$ pc	0.09
FUV Radiation Affects Solar Nebula	$G_0 \geq 2000$	0.50
Solar Nebula Survives Radiation	$G_0 \leq 10^4$	0.80

② Скопление без ЗБ.

a. SN

i) $P_{ram} = (\rho v^2)_{SN} = \underbrace{A_{SN}}_{\approx 1} \cdot \frac{E_{SN}}{r^3}$

$P_\odot = \frac{G M_\odot \Sigma}{r_d^2}$

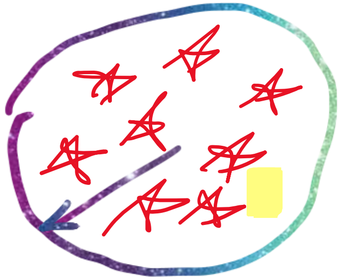
ii) $\frac{M_{ej} \cdot v_{SN}}{4\pi r^2} = \left(\frac{2 G M_\odot}{r_d}\right)^{1/2} \Sigma(r_d) \Rightarrow 0,1$ pc

iii) Обогащ. ^{60}Fe $\quad X_{Fe60} = 1,1 \cdot 10^{-9}$. $\quad$ SN: $M_j \approx 10^{-4} M_\odot$ Fe60

$X_j = f_j \frac{M_j}{M_d} \cdot \frac{\pi r_d^2}{4\pi d^2}$ $\quad M_d = 0.05 M_\odot$ $\quad r_d = 30$ ае

$d \sim 0.1 \div 0.3$ pc

8. Becslés UV.



N

R

r

IMF

$\langle L_{UV} \rangle_*$ (IMF)

$$F_{UV} = f_m \frac{N \cdot \langle L_{UV} \rangle_*}{4\pi r^2} =$$

$f_m \simeq 0{,}8$

$r \equiv \langle r \rangle = \frac{2}{3} R$

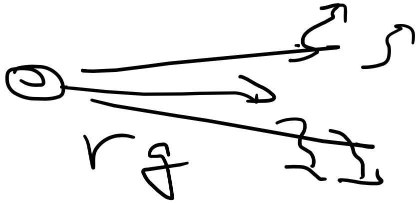
$$R = R_0 \left(\frac{N}{N_0}\right)^{\alpha}$$

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

$R_0 = 1\,\mathrm{pc}$

$N_0 = 300$

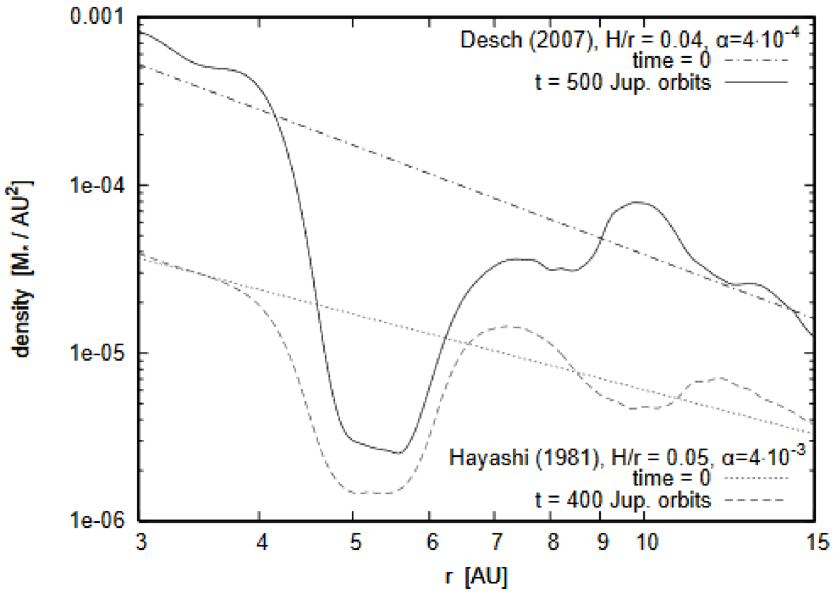
$\alpha \simeq 1/2$



$$r_g = \frac{G M_*}{a_s^2} = \frac{G M_* \langle \mu \rangle}{kT} = 100\,\mathrm{au} \left(\frac{T}{1000\,\mathrm{K}}\right)^{-1}$$

$$N \sim 3000 \Rightarrow \tau_{UV} \sim \underline{\underline{10}}\ \mathrm{Myr}$$

③ MMSN



Desch (2007), H/r = 0.04, α=4·10^-4
time = 0
t = 500 Jup. orbits
Hayashi (1981), H/r = 0.05, α=4·10^-3
time = 0
t = 400 Jup. orbits
0.001
1e-04
1e-05
1e-06
density [M* / AU^2]
3
4
5
6
7
8
9
10
15
r [AU]

New MMSN model

Based on the Nice model

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

Gas/solid = 67 (i.e. solids = 1.5%)

0,49% – rock
0,57% – water ice
0.33% – methan
0.097% – ammon

INITIAL SOLAR SYSTEM CONDITIONS

Planet	M_{aug} [a] ($M_\oplus$)	r_{in} (AU)	r_0 (AU)	r_{out} (AU)	Σ [a] (g cm^{-2})
Jupiter	1747 ± 1075	4.45[b]	5.45	6.68	546.8
Saturn	1411 ± 470	6.68	8.18	9.70	244.5
Neptune	1032 ± 91	9.70	11.5	12.8	123.2
Uranus	843 ± 124	12.8	14.2	15.9[a]	77.2
Disk[c]	2353 ± 336	15.9[b]	22.5	30.0	31.2

Initial positions: Jupiter – 5.45 AU; Saturn – 8.18 AU; Neptune – 11.5 AU; Uranus – 14.2 AU
Uranus and Neptune change places during migration!

Desch 2007

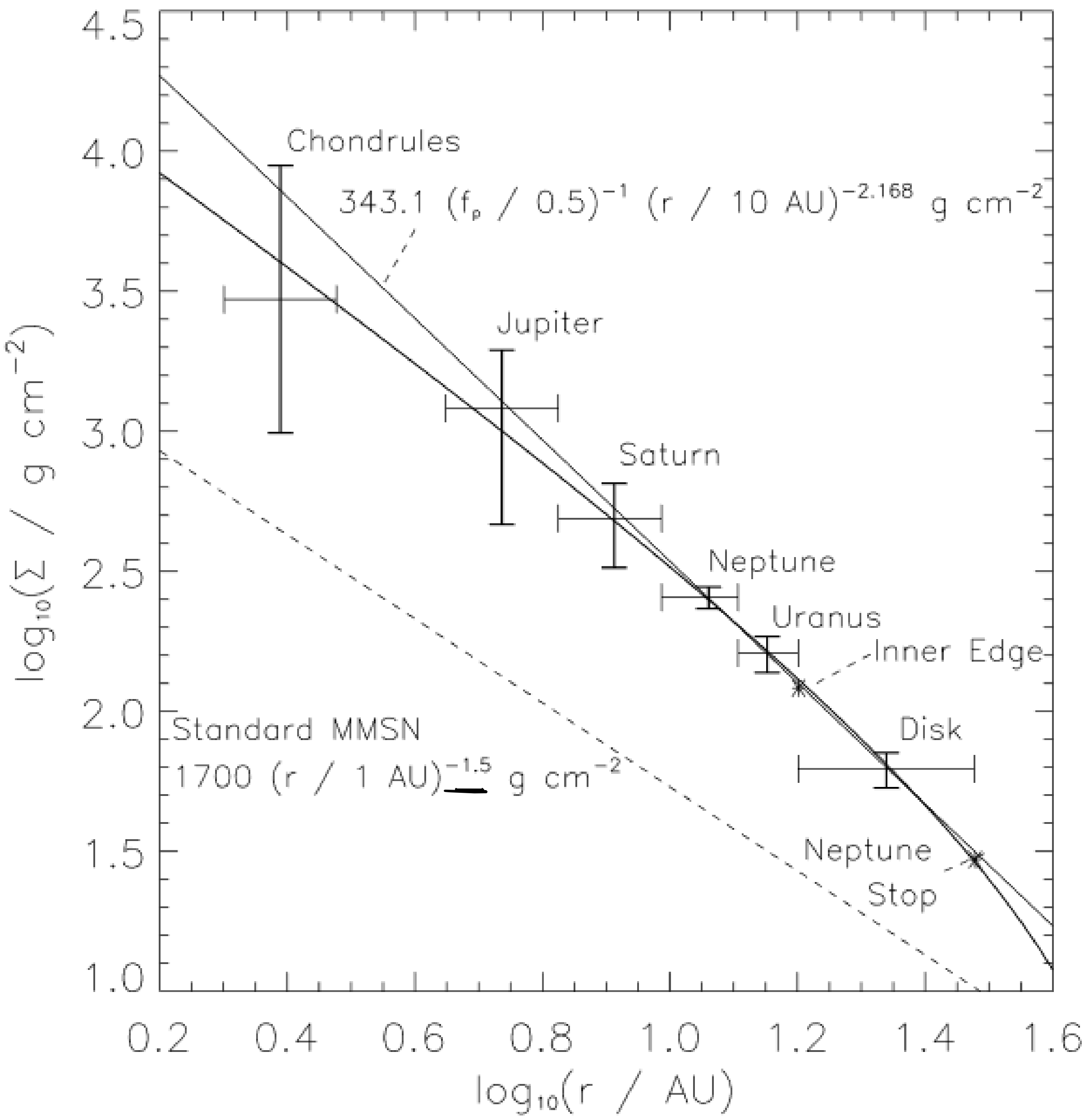
Surface density

$$\Sigma(r) = 343\left(\frac{f_p}{0.5}\right)^{-1}\left(\frac{r}{10\ \mathrm{AU}}\right)^{-2.168}\ \mathrm{g\ cm^{-2}}$$

$$\rho_{\mathrm{gas}}(r,0) = 1.93\times10^{-11}\left(\frac{f_p}{0.5}\right)^{-1}\left(\frac{r}{10\ \mathrm{AU}}\right)^{-3.4537}\ \mathrm{g\ cm^{-3}}.$$

Steep profile is achieved thanks to photoevaporation of the outer parts of the disc due to influence of a massive star.
Mass partly flows out to compensate losses.

0,06 $M_\odot$



Desch 2007