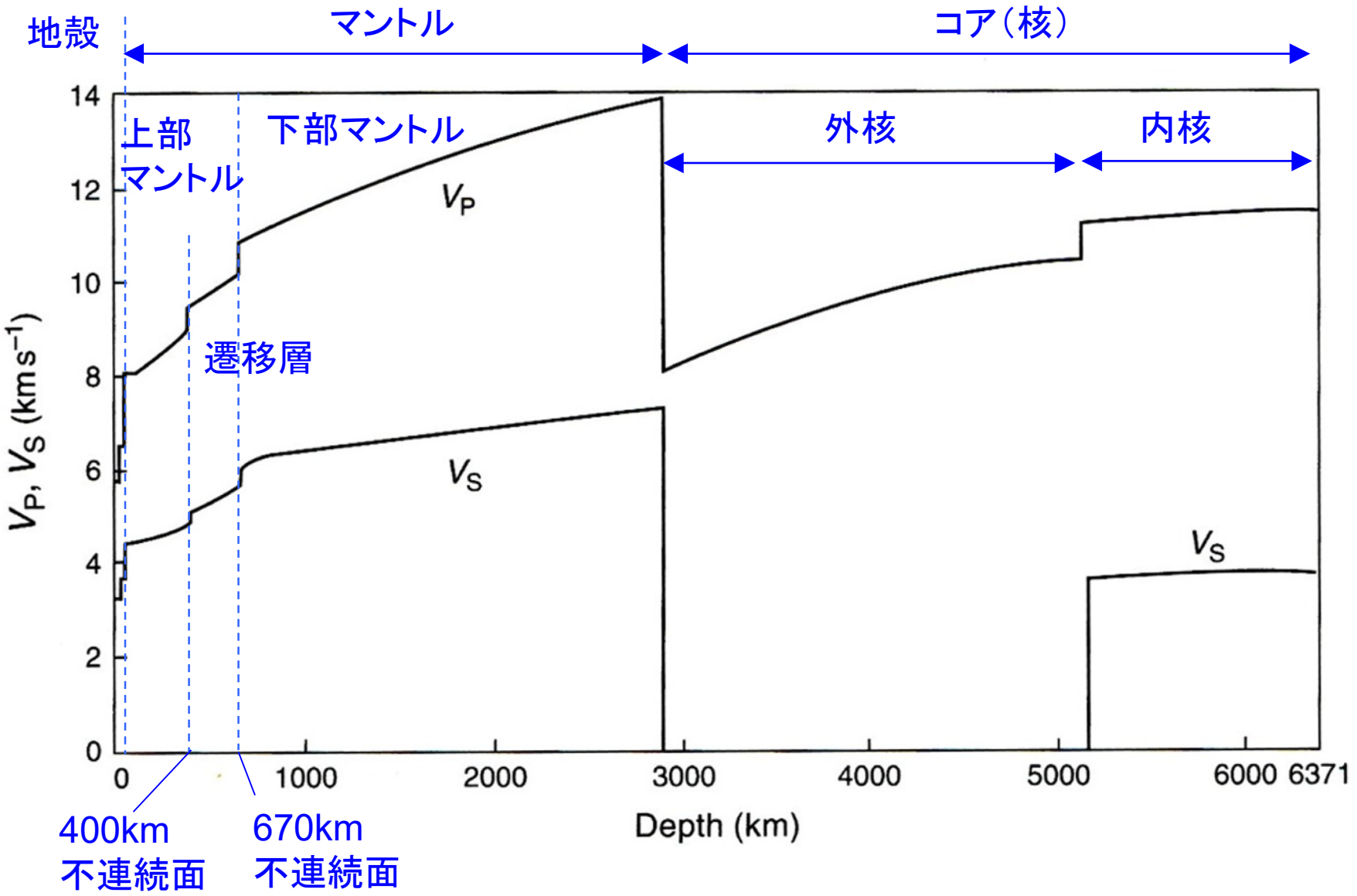
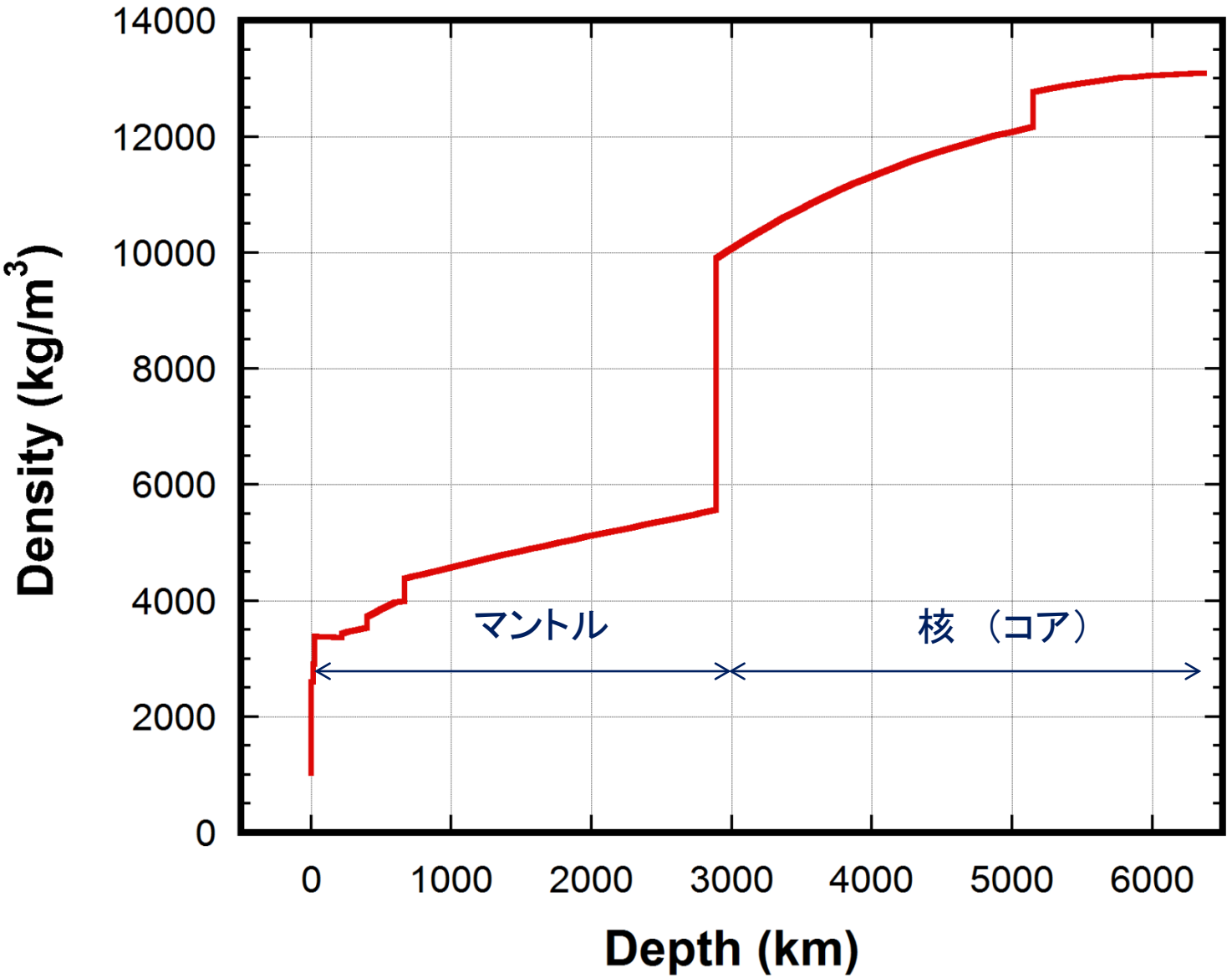
地球内部物理学

2019.12.24

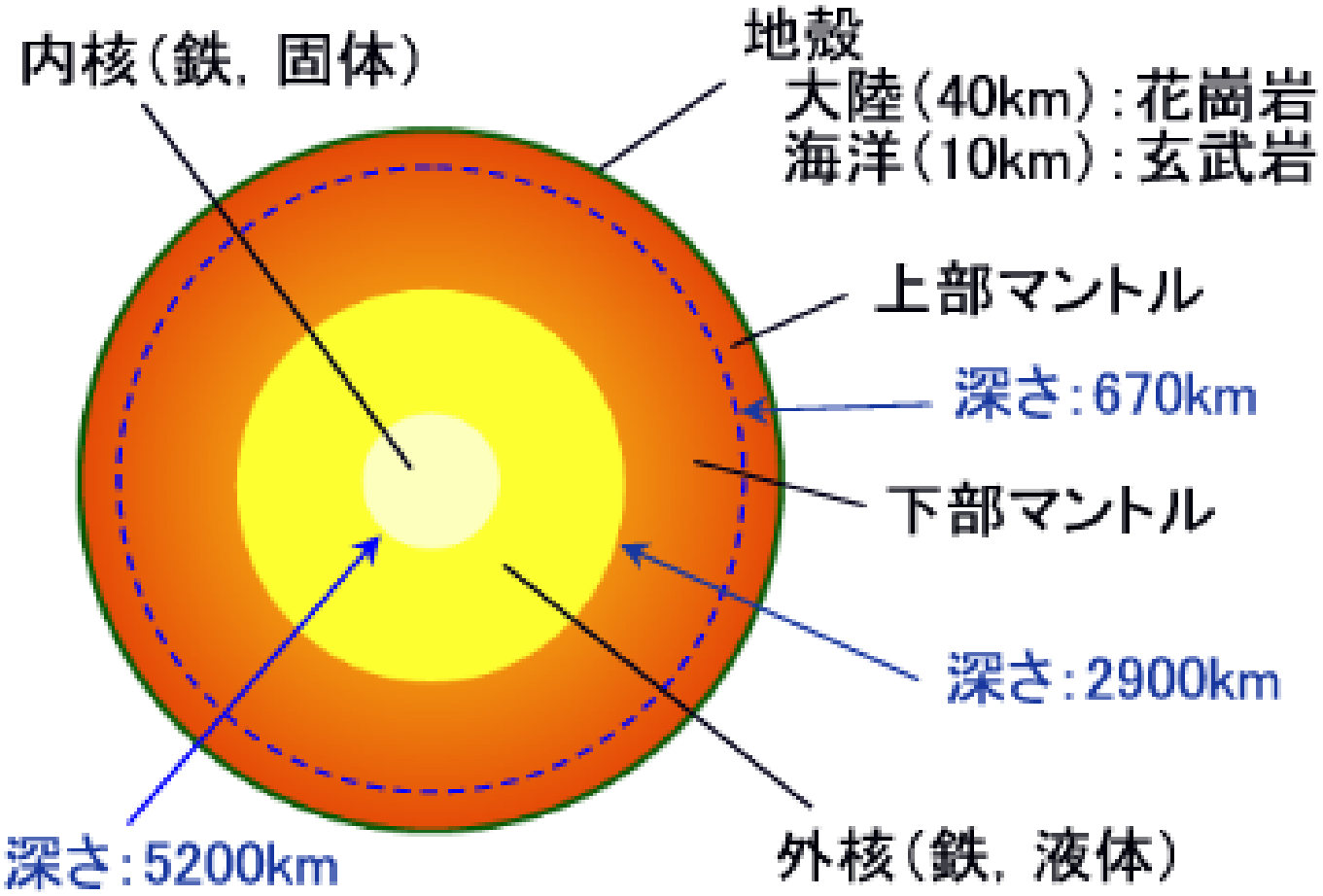
球対称地球モデル

IASP91

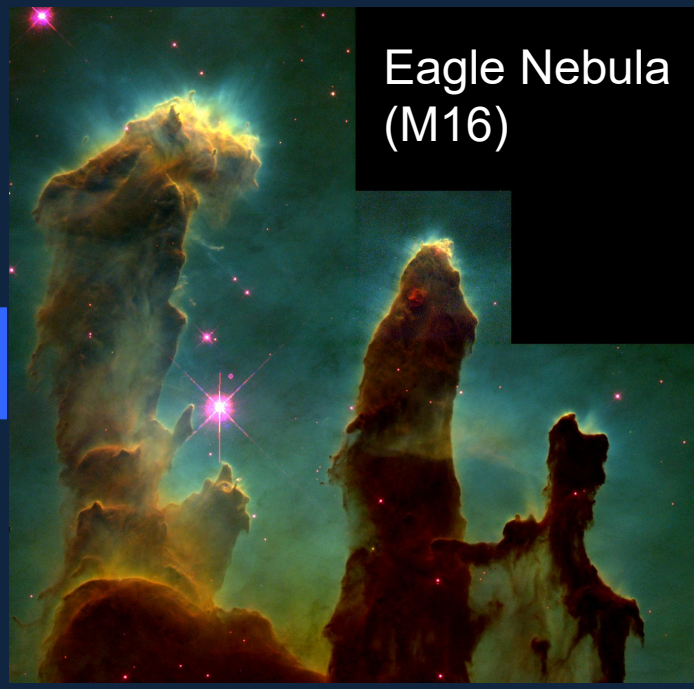



14000
12000
10000
8000
6000
4000
2000
0
Density (kg/m3)
マントル
核 （コア）
0
1000
2000
3000
4000
5000
6000
Depth (km)

地球の層構造

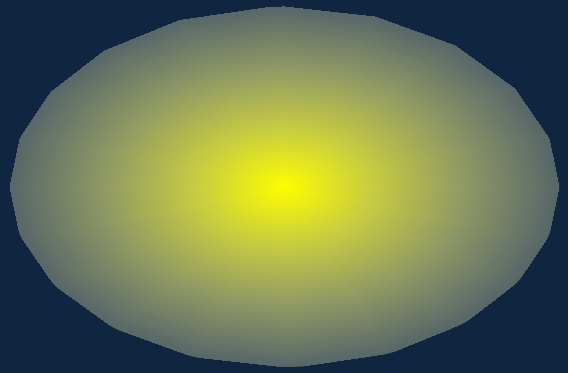

内核（鉄，固体）
地殻
大陸（40km）：花崗岩
海洋（10km）：玄武岩
上部マントル
深さ：670km
下部マントル
深さ：2900km
深さ：5200km
外核（鉄，液体）

星の形成



銀河内の密度のゆらぎ

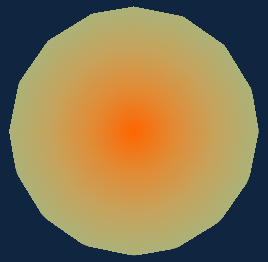
星間雲（ガス，固体粒子）



原始太陽系星雲

重力収縮

赤外線の放射

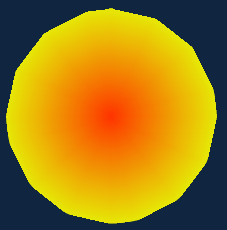


原始太陽

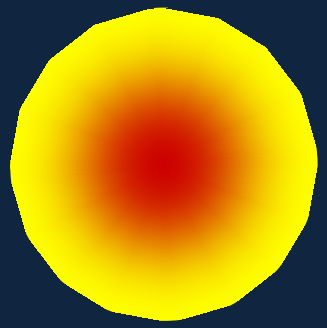
重力収縮

H　燃焼の開始

温度上昇
T=1000万K



核融合反応の開始

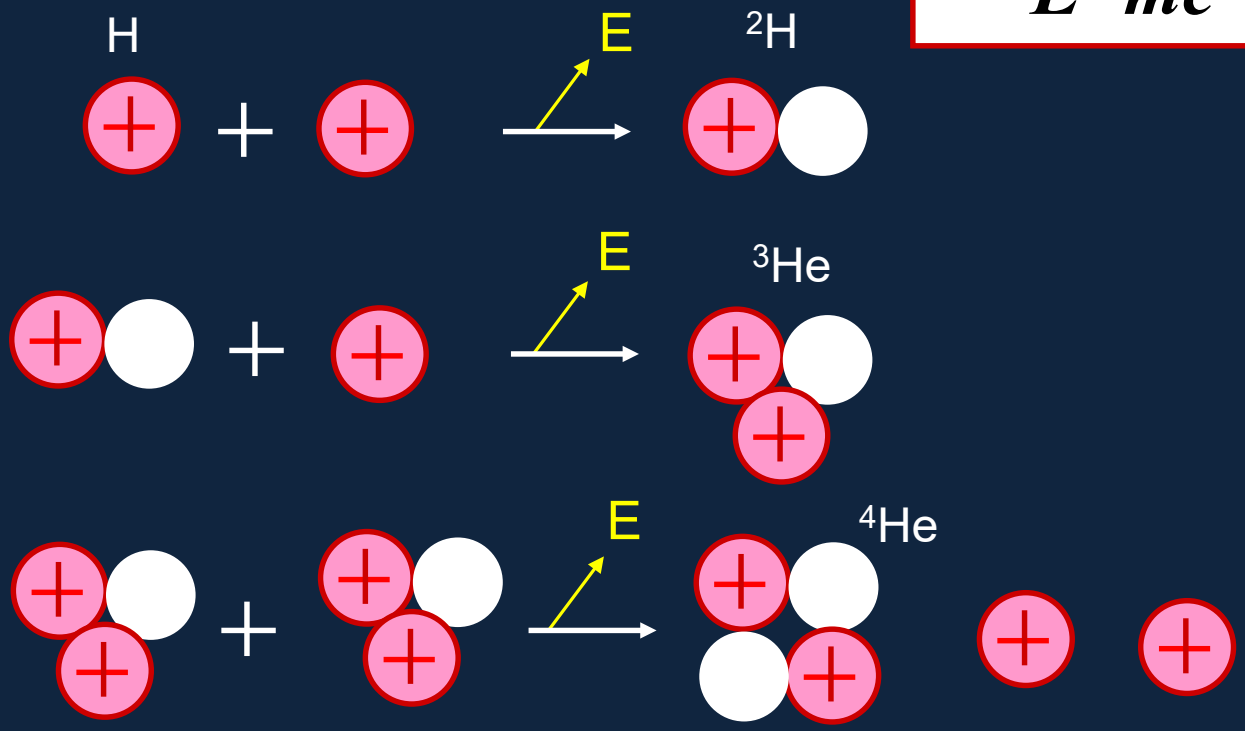


T=1000万K

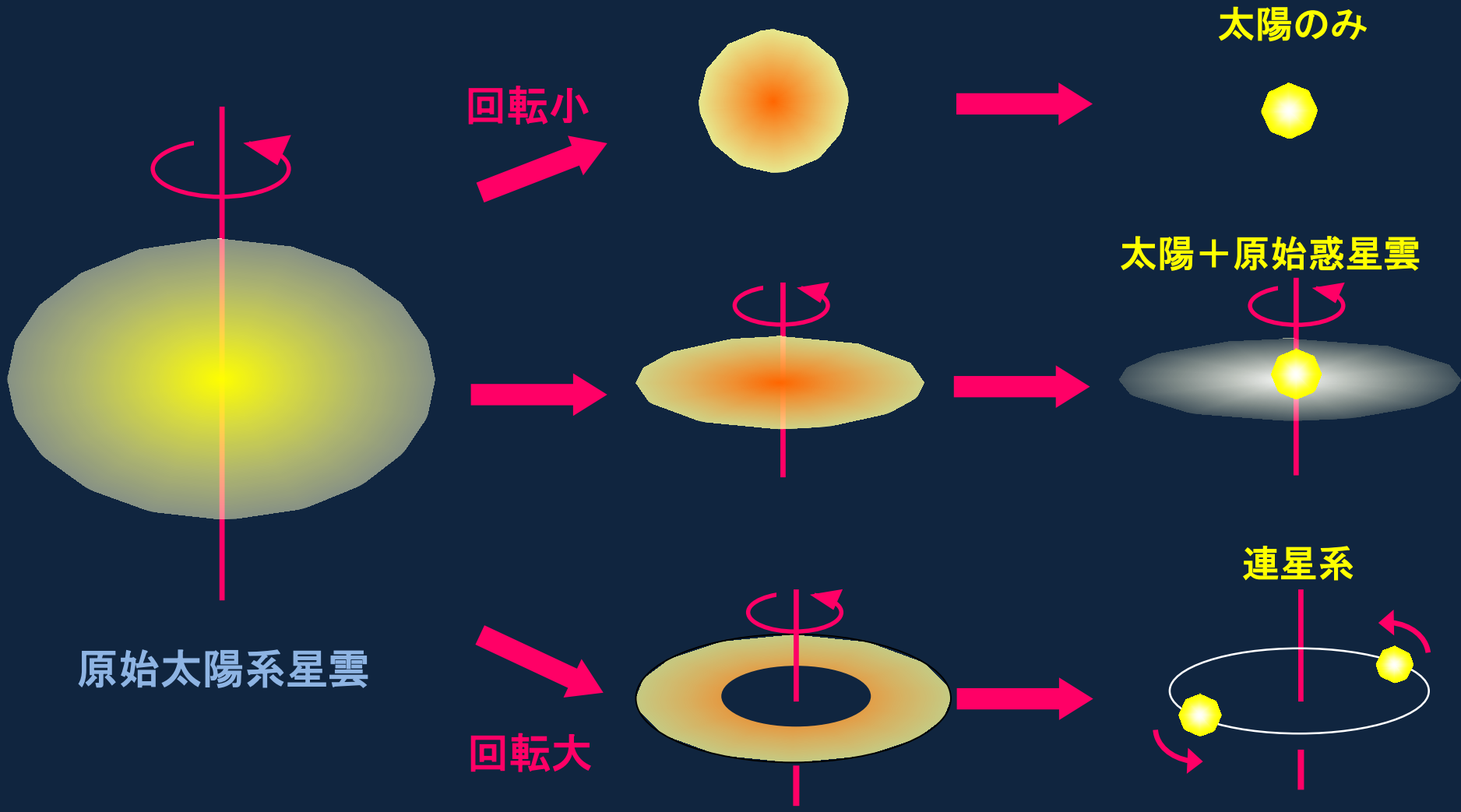
水素- ヘリウム反応の開始

内部圧力と重力がつりあう

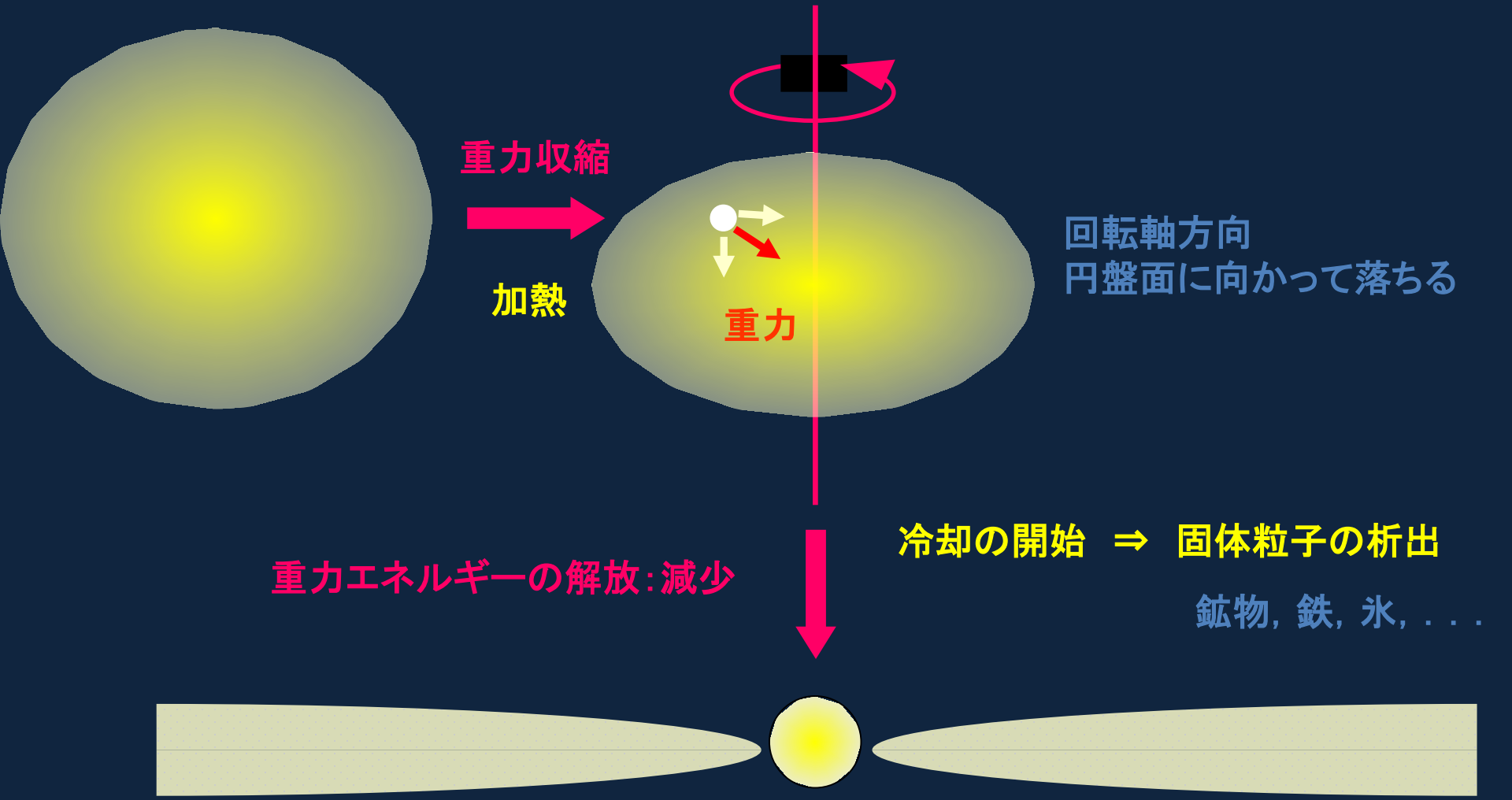
$E=mc^2$



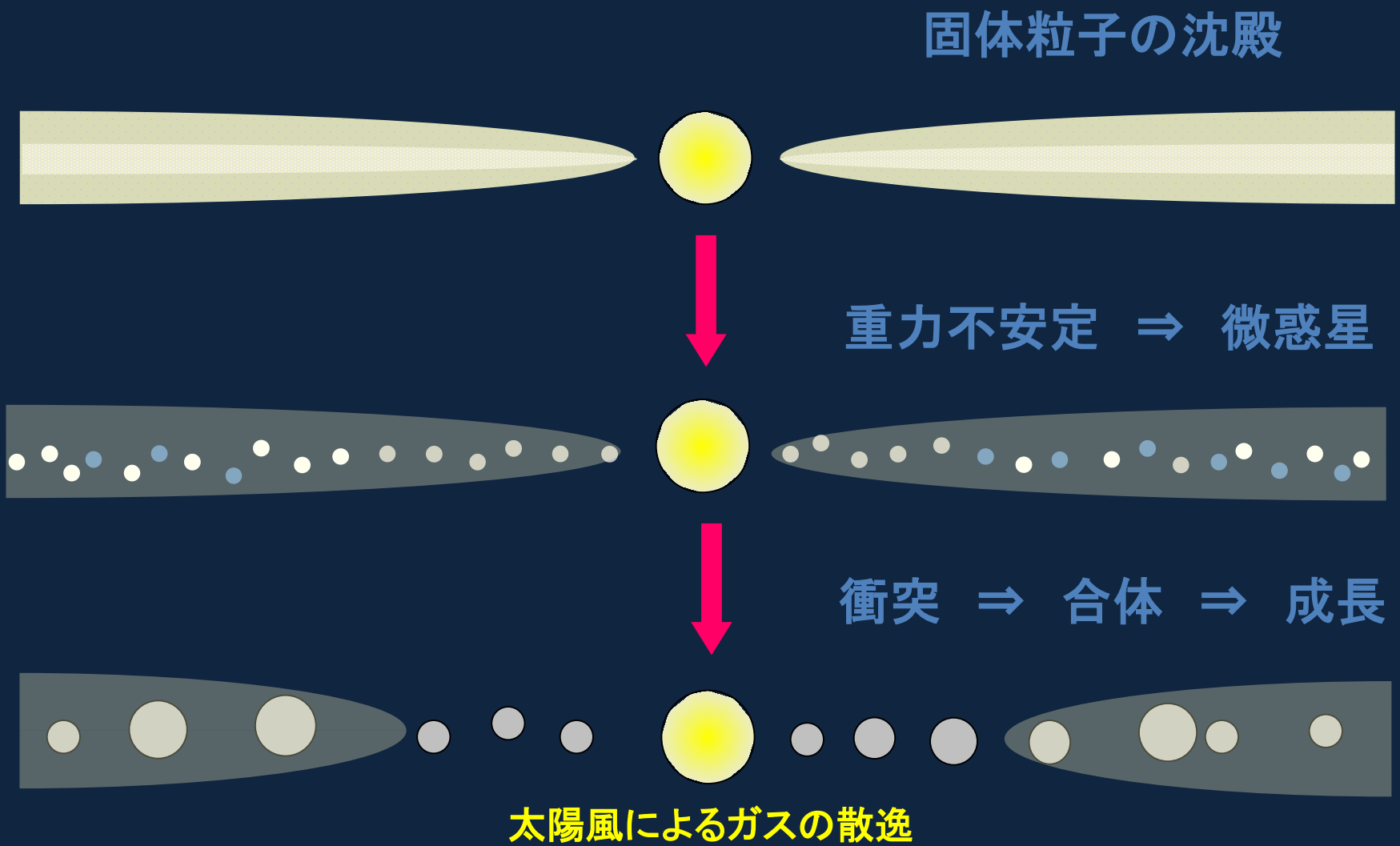
惑星系の形成　⇒　回転がカギ



原始太陽系星雲の進化


重力収縮
加熱
重力
回転軸方向
円盤面に向かって落ちる
重力エネルギーの解放：減少
冷却の開始　⇒　固体粒子の析出
鉱物，鉄，氷，．．．

固体粒子⇒微惑星⇒惑星



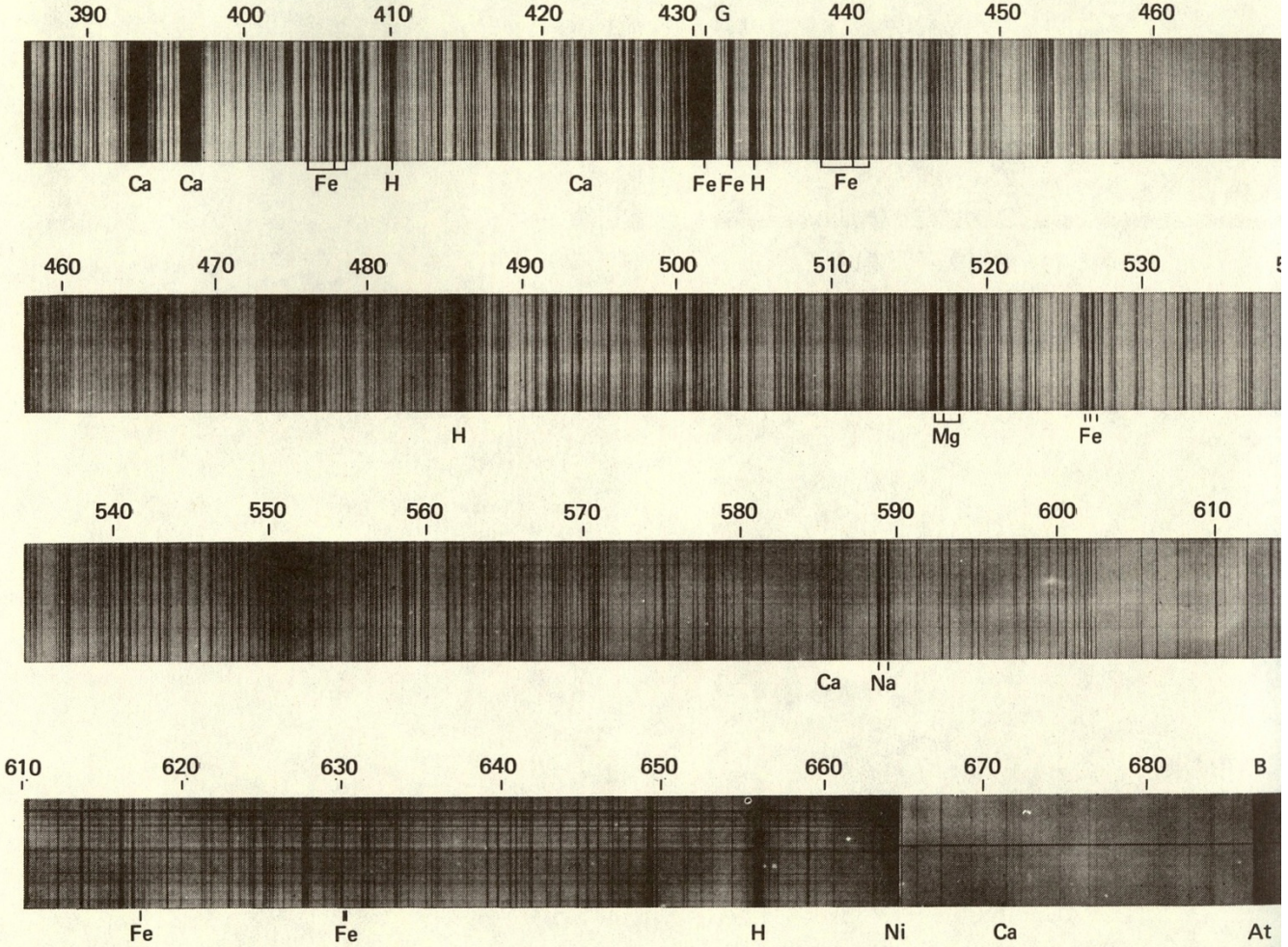
VII-3　太陽スペクトル

図 VII-11　太陽の吸収スペクトル

[W. J. Kaufman, 1978 : *Exploration of the Solar System,* p. 114, Macmillan Pub. Co.]

パロマー山天文台の 13 フィート太陽分光写真儀による．フラウンホーファー線の記号と波長は表 IX-7 参照

波長は nm．Palomar Observatory Photograph.



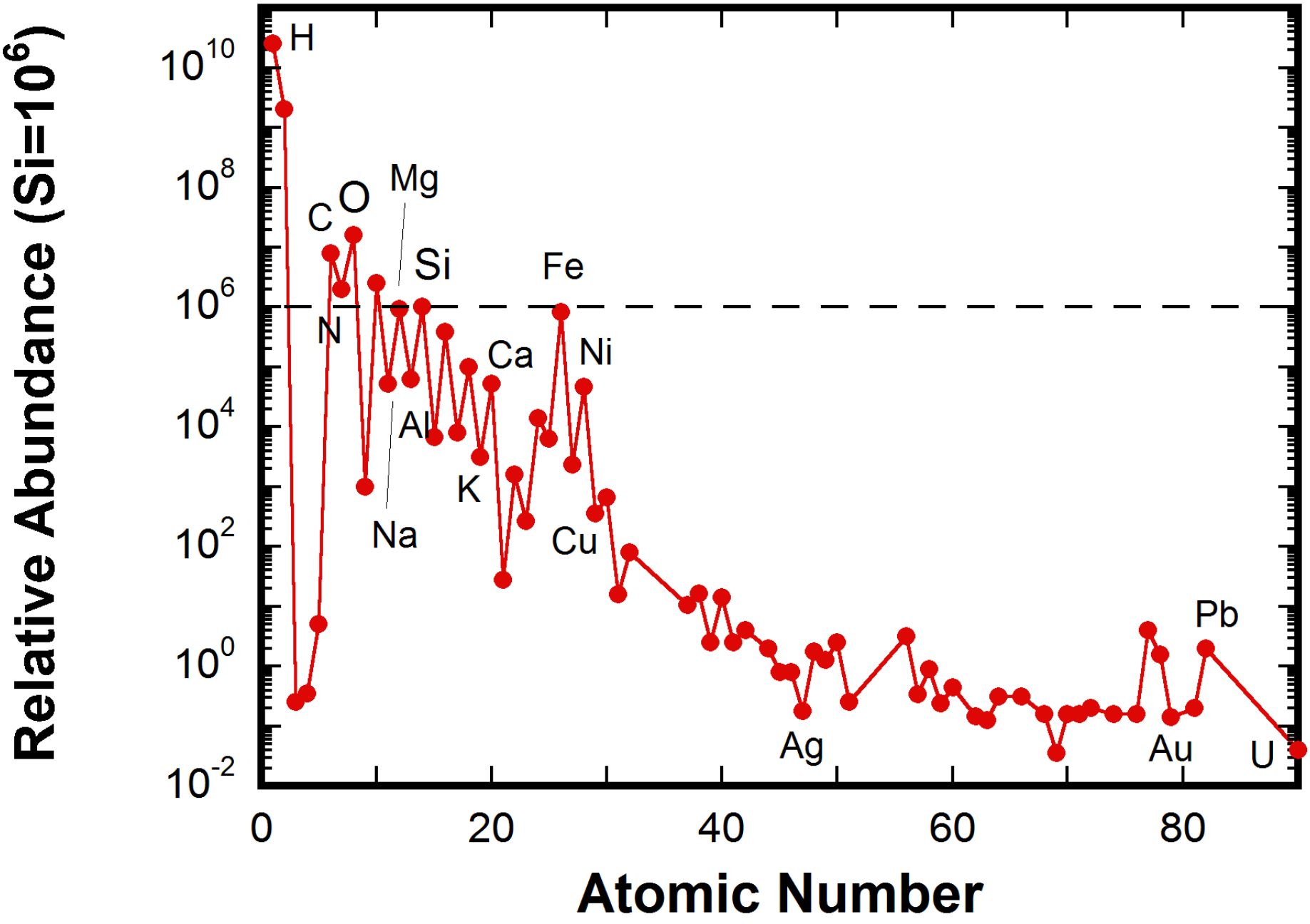
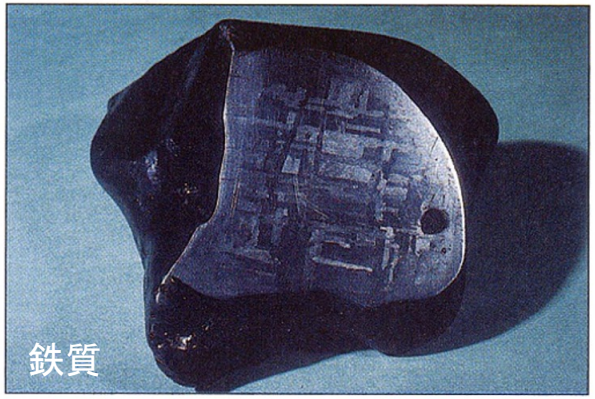
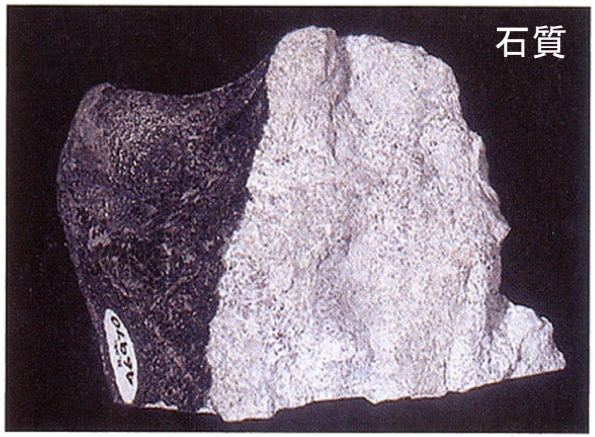

Relative Abundance (Si=10^6)
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
0
20
40
60
80
Atomic Number
H
C
O
N
Mg
Si
Na
Al
K
Ca
Fe
Ni
Cu
Ag
Au
Pb
U

Figure 1.17 Different types of meteorites: (a) a cut and polished surface of an iron meteorite that has been etched with acid to reveal details of its internal texture; (b) a carbonaceous chondrite; (c) a stony meteorite with a basaltic composition; (d) a stony-iron meteorite, or pallasite, with olivine crystals set in a metal matrix; (e) a relatively large mm-sized chondrule from a carbonaceous chondrite (Bokkeveld meteorite), showing individual crystals within it; (f) a collection of individual chondrules, each less than 1 mm in diameter, from an ordinary chondrite (Sharps meteorite). (Natural History Museum)



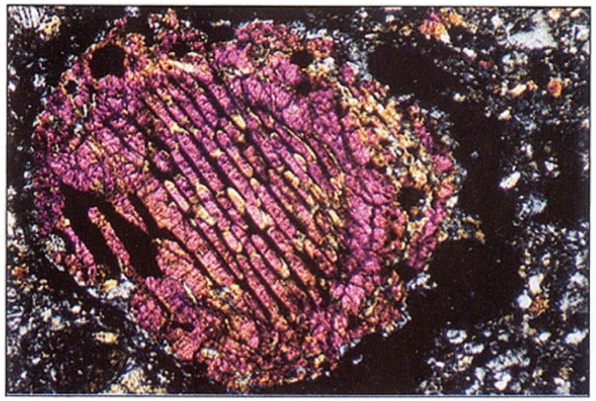
(a)

(b)

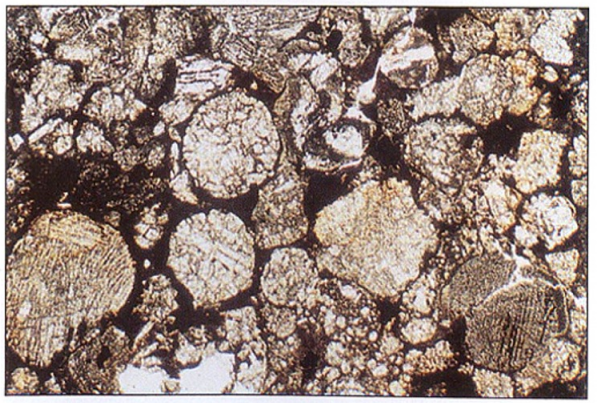


(c)

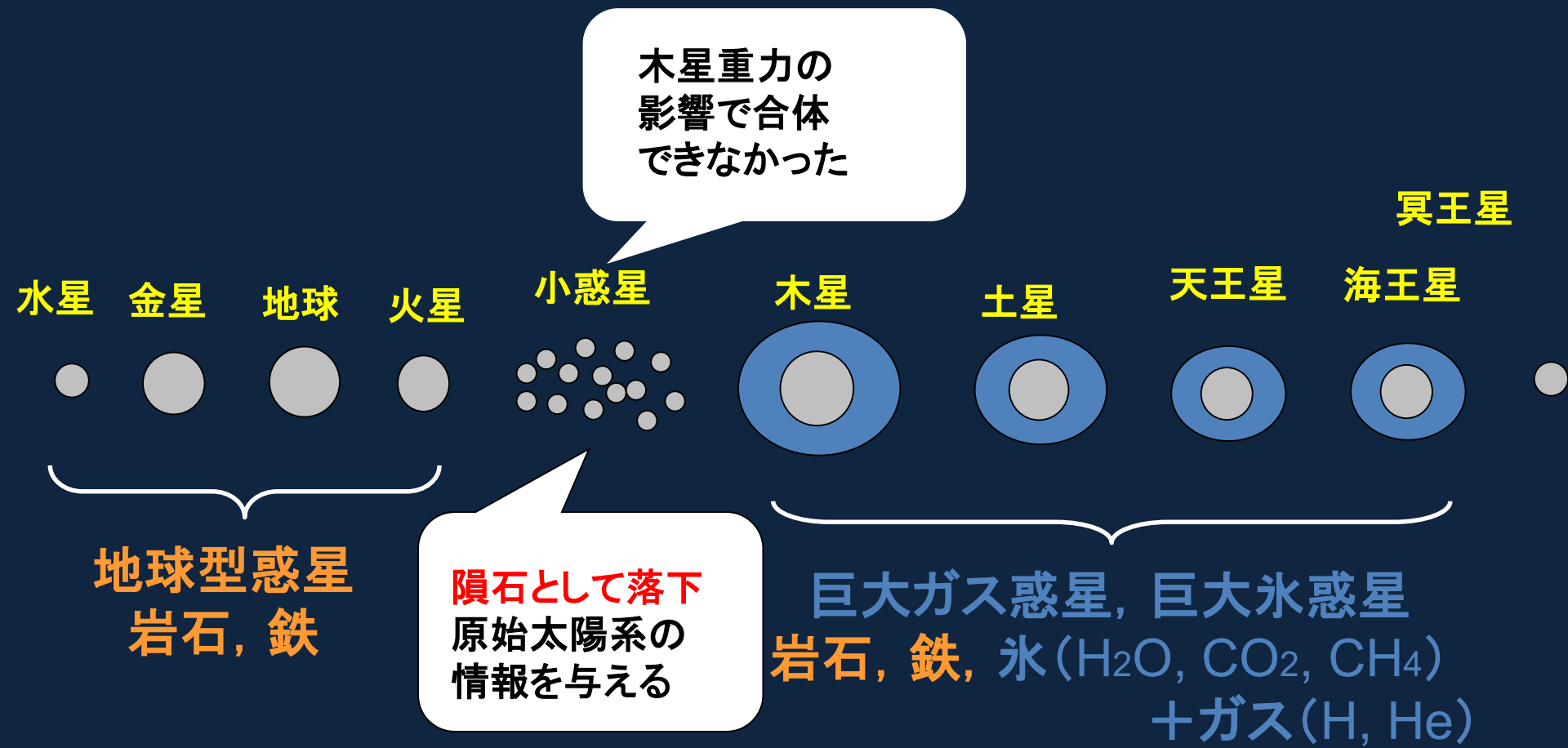
(d)


(e)

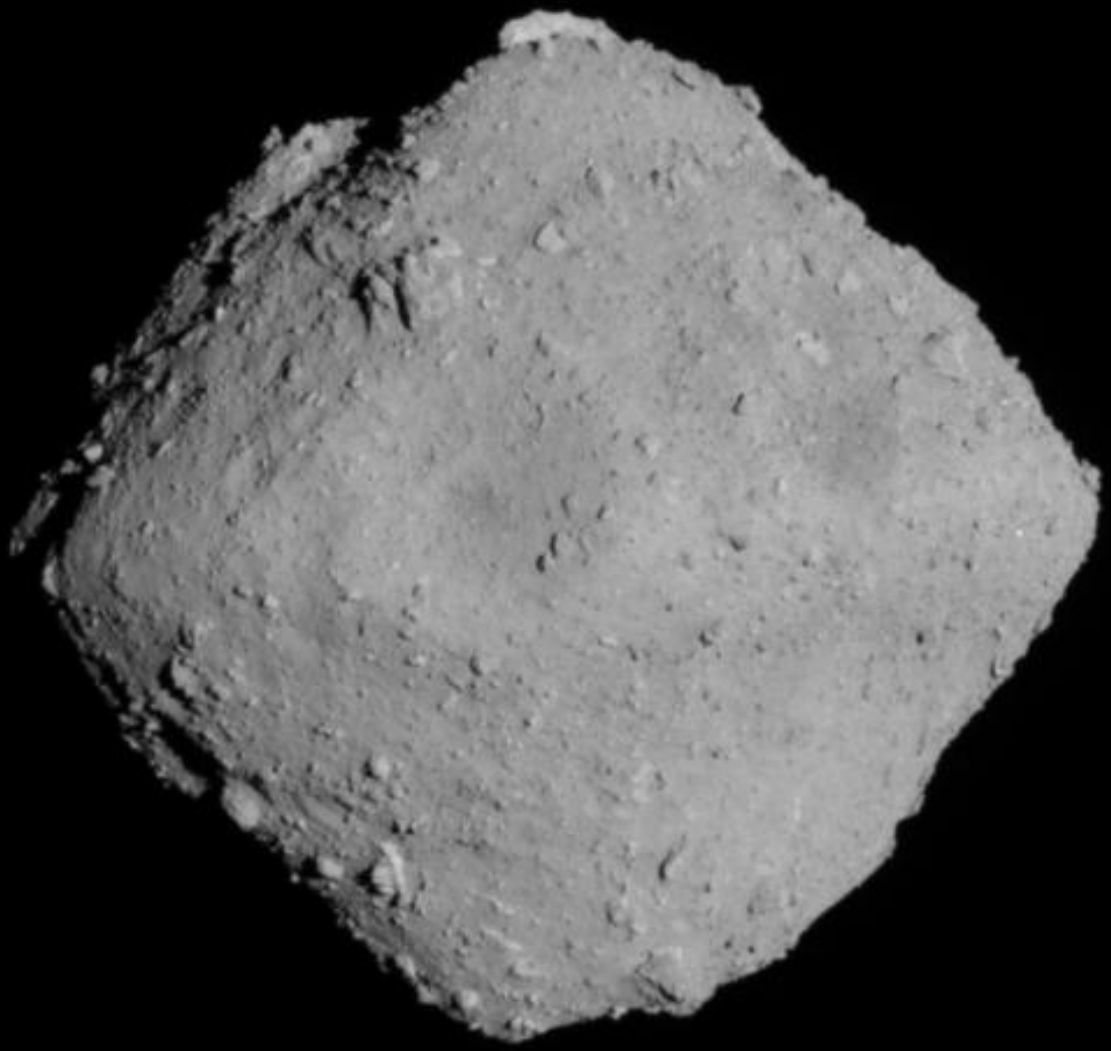
chondrule

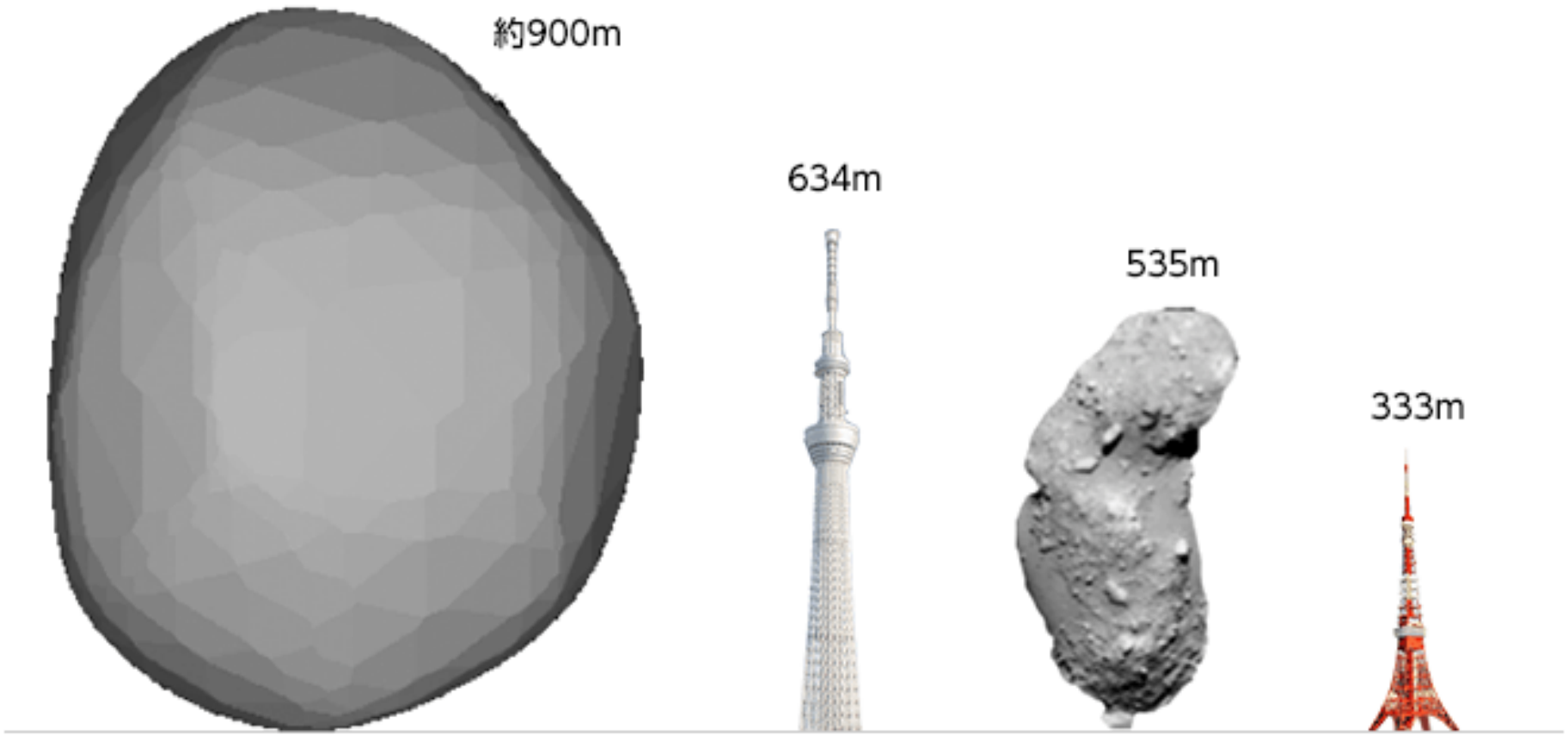

(f)

構成物質の違い

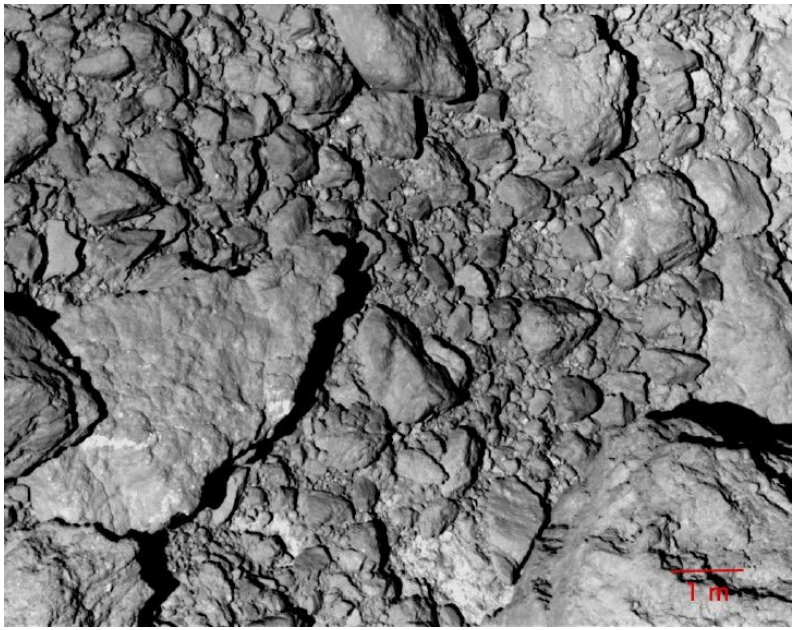


太陽からの距離（温度）によって材料物質に差




約900m
634m
535m
333m

小惑星　イトカワ



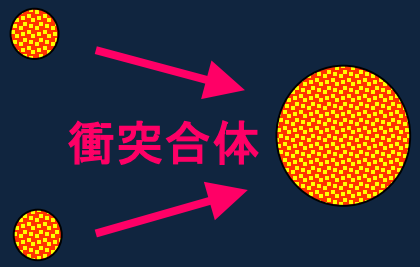
密度　1.9 g/cm^3

層構造の形成

微惑星

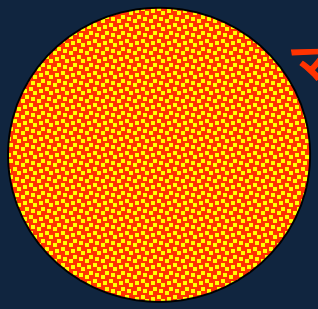
岩石質

鉄質



衝突合体

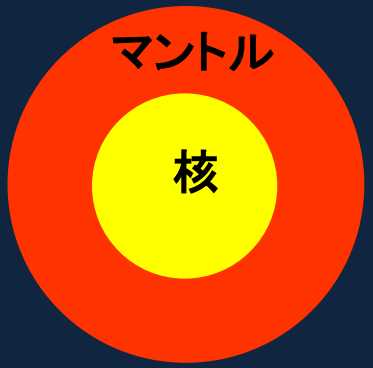
合体成長



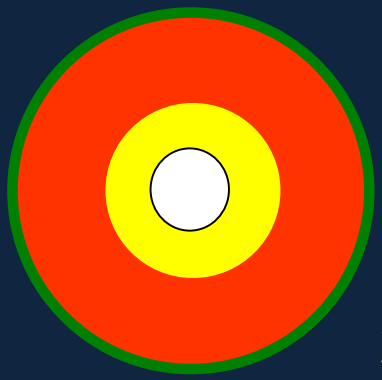
マグマオーシャン

重力分離

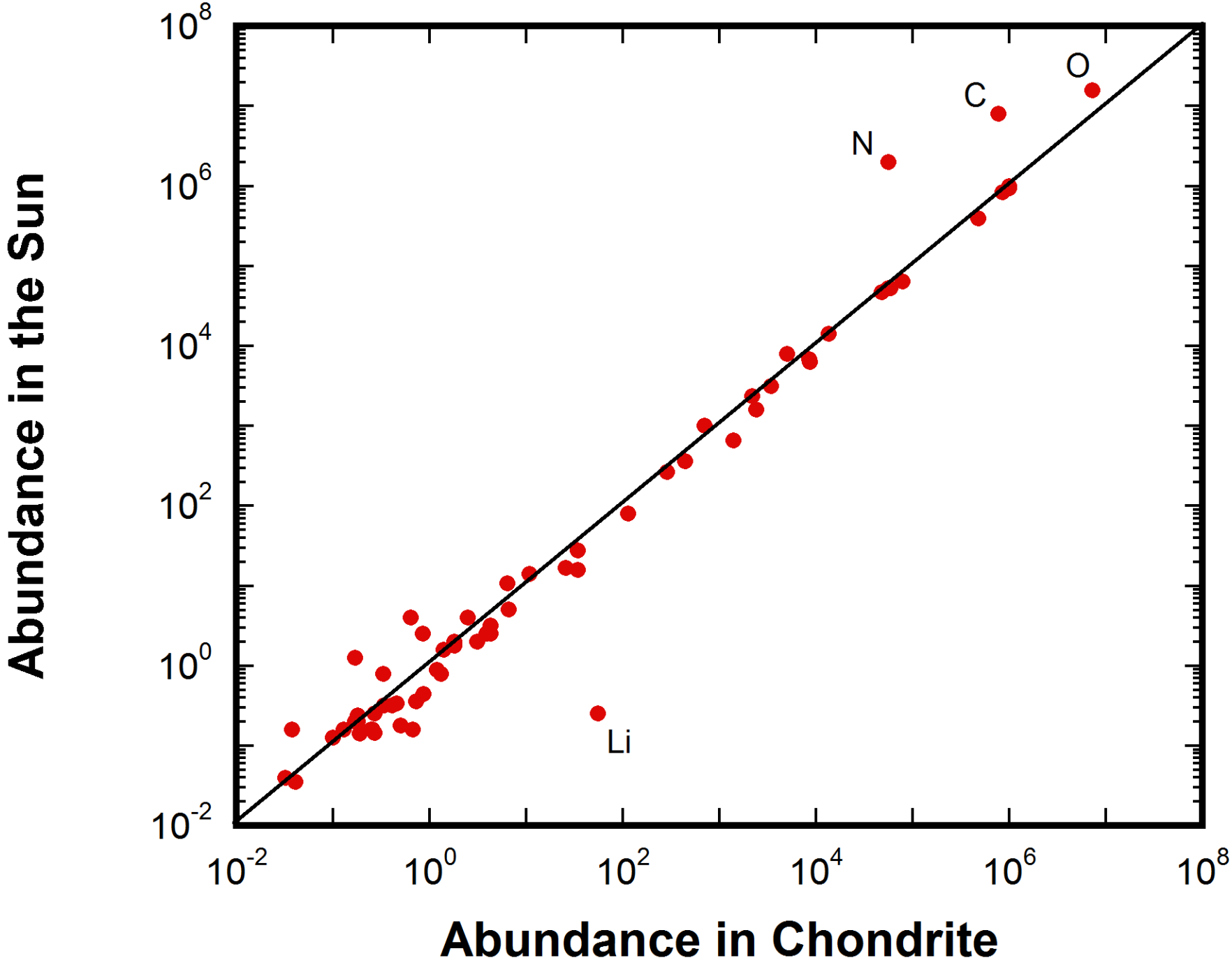
重力エネルギーの解放
⇒ 高温 ⇒ 部分融解

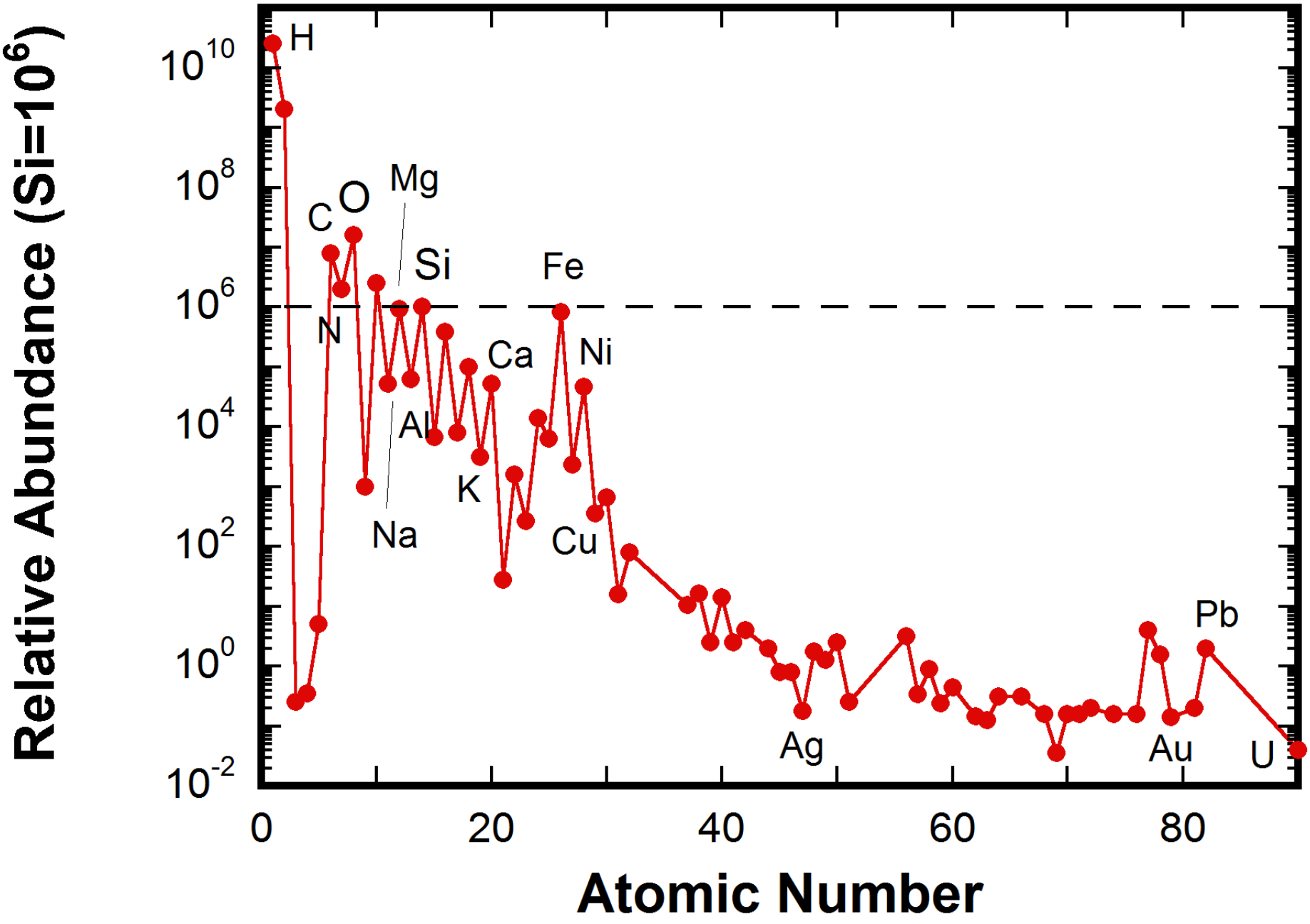


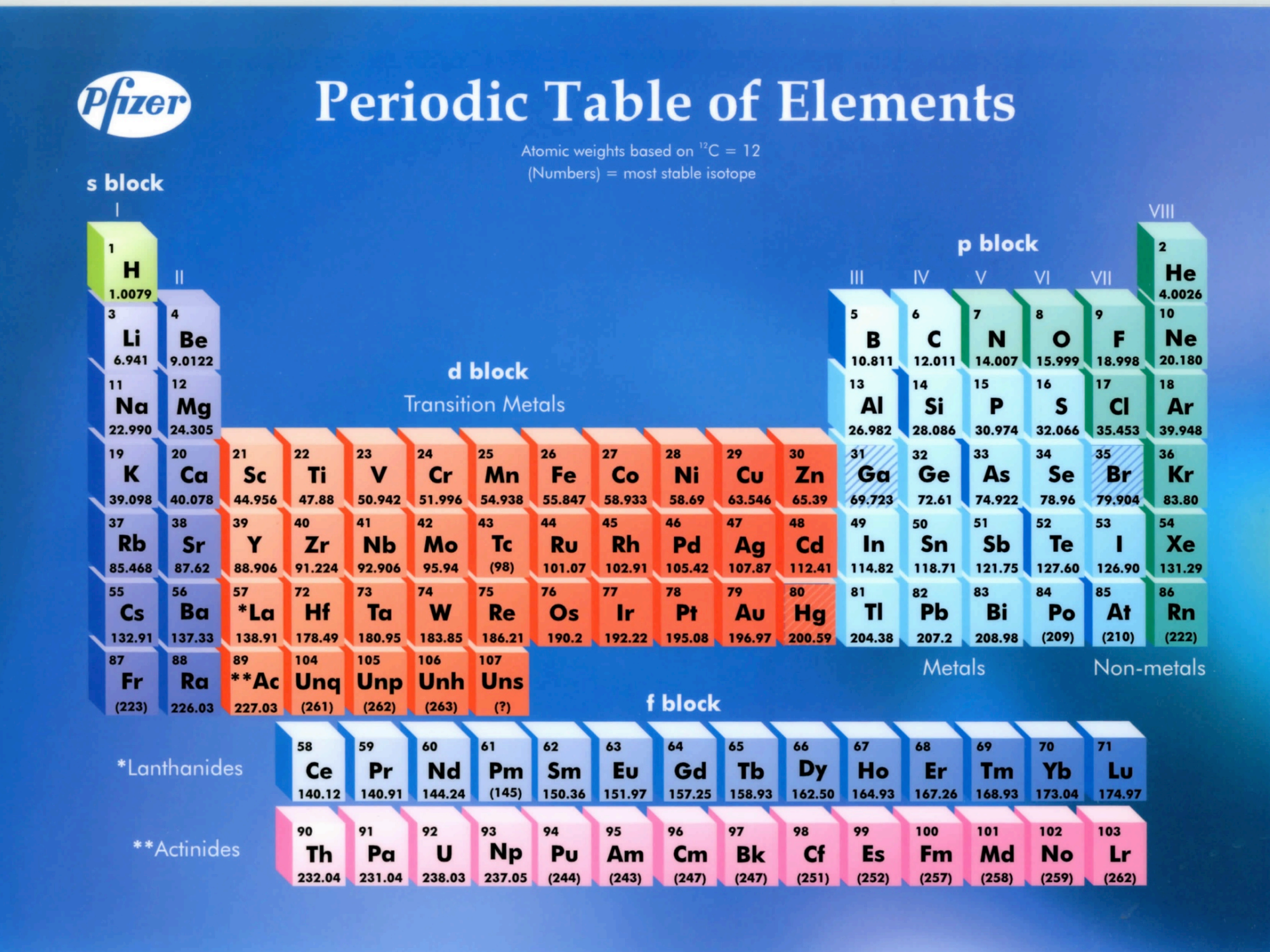
冷却 ⇒ 内核（固体）の形成



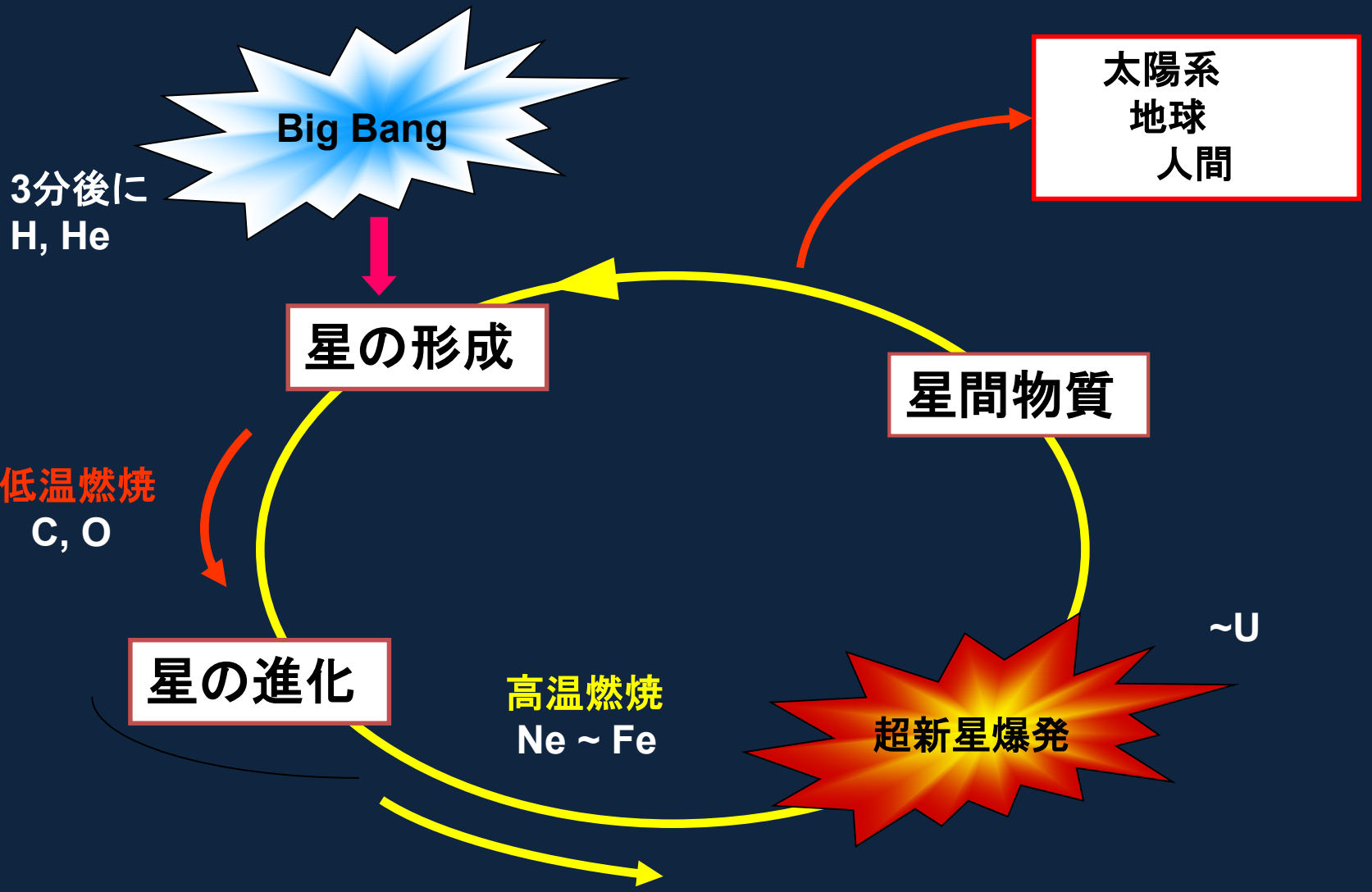
マントル低融点成分（マグマ，低密度）
の分離（火山活動）
⇒ 地殻の形成


Abundance in the Sun
Abundance in Chondrite
10^{8}
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-2}
10^{0}
10^{2}
10^{4}
10^{6}
10^{8}
O
C
N
Li

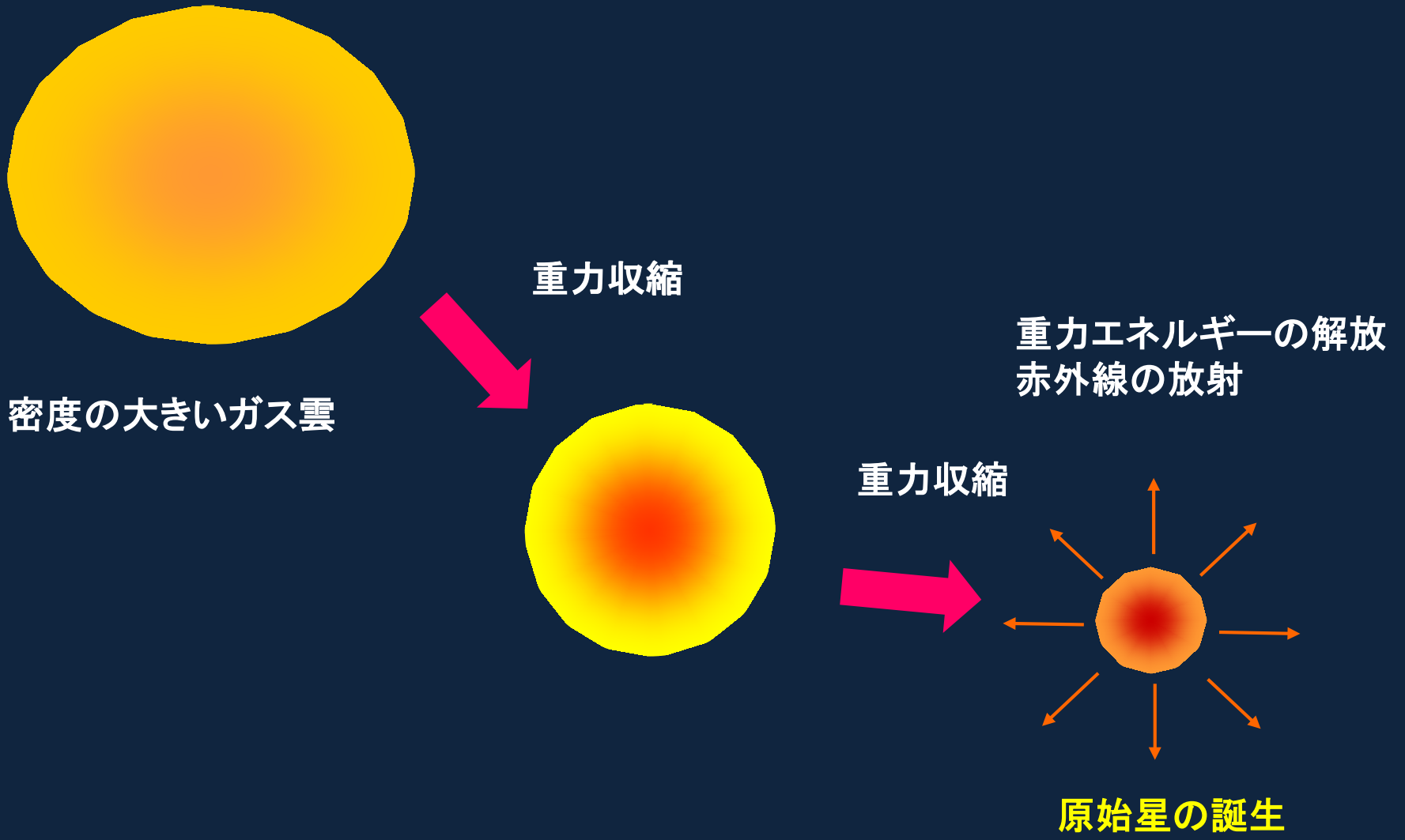

Relative Abundance (Si=10^6)
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
0
20
40
60
80
Atomic Number
H
C
O
N
Mg
Si
Na
Al
K
Ca
Fe
Ni
Cu
Ag
Au
Pb
U


Pfizer
Periodic Table of Elements
Atomic weights based on $^{12}C = 12$
(Numbers) = most stable isotope
s block
d block
Transition Metals
p block
I
II
III
IV
V
VI
VII
VIII
1 H 1.0079
2 He 4.0026
3 Li 6.941
4 Be 9.0122
5 B 10.811
6 C 12.011
7 N 14.007
8 O 15.999
9 F 18.998
10 Ne 20.180
11 Na 22.990
12 Mg 24.305
13 Al 26.982
14 Si 28.086
15 P 30.974
16 S 32.066
17 Cl 35.453
18 Ar 39.948
19 K 39.098
20 Ca 40.078
21 Sc 44.956
22 Ti 47.88
23 V 50.942
24 Cr 51.996
25 Mn 54.938
26 Fe 55.847
27 Co 58.933
28 Ni 58.69
29 Cu 63.546
30 Zn 65.39
31 Ga 69.723
32 Ge 72.61
33 As 74.922
34 Se 78.96
35 Br 79.904
36 Kr 83.80
37 Rb 85.468
38 Sr 87.62
39 Y 88.906
40 Zr 91.224
41 Nb 92.906
42 Mo 95.94
43 Tc (98)
44 Ru 101.07
45 Rh 102.91
46 Pd 105.42
47 Ag 107.87
48 Cd 112.41
49 In 114.82
50 Sn 118.71
51 Sb 121.75
52 Te 127.60
53 I 126.90
54 Xe 131.29
55 Cs 132.91
56 Ba 137.33
57 *La 138.91
72 Hf 178.49
73 Ta 180.95
74 W 183.85
75 Re 186.21
76 Os 190.2
77 Ir 192.22
78 Pt 195.08
79 Au 196.97
80 Hg 200.59
81 Tl 204.38
82 Pb 207.2
83 Bi 208.98
84 Po (209)
85 At (210)
86 Rn (222)
87 Fr (223)
88 Ra 226.03
89 **Ac 227.03
104 Unq (261)
105 Unp (262)
106 Unh (263)
107 Uns (?)
Metals
Non-metals
f block
*Lanthanides
58 Ce 140.12
59 Pr 140.91
60 Nd 144.24
61 Pm (145)
62 Sm 150.36
63 Eu 151.97
64 Gd 157.25
65 Tb 158.93
66 Dy 162.50
67 Ho 164.93
68 Er 167.26
69 Tm 168.93
70 Yb 173.04
71 Lu 174.97
**Actinides
90 Th 232.04
91 Pa 231.04
92 U 238.03
93 Np 237.05
94 Pu (244)
95 Am (243)
96 Cm (247)
97 Bk (247)
98 Cf (251)
99 Es (252)
100 Fm (257)
101 Md (258)
102 No (259)
103 Lr (262)

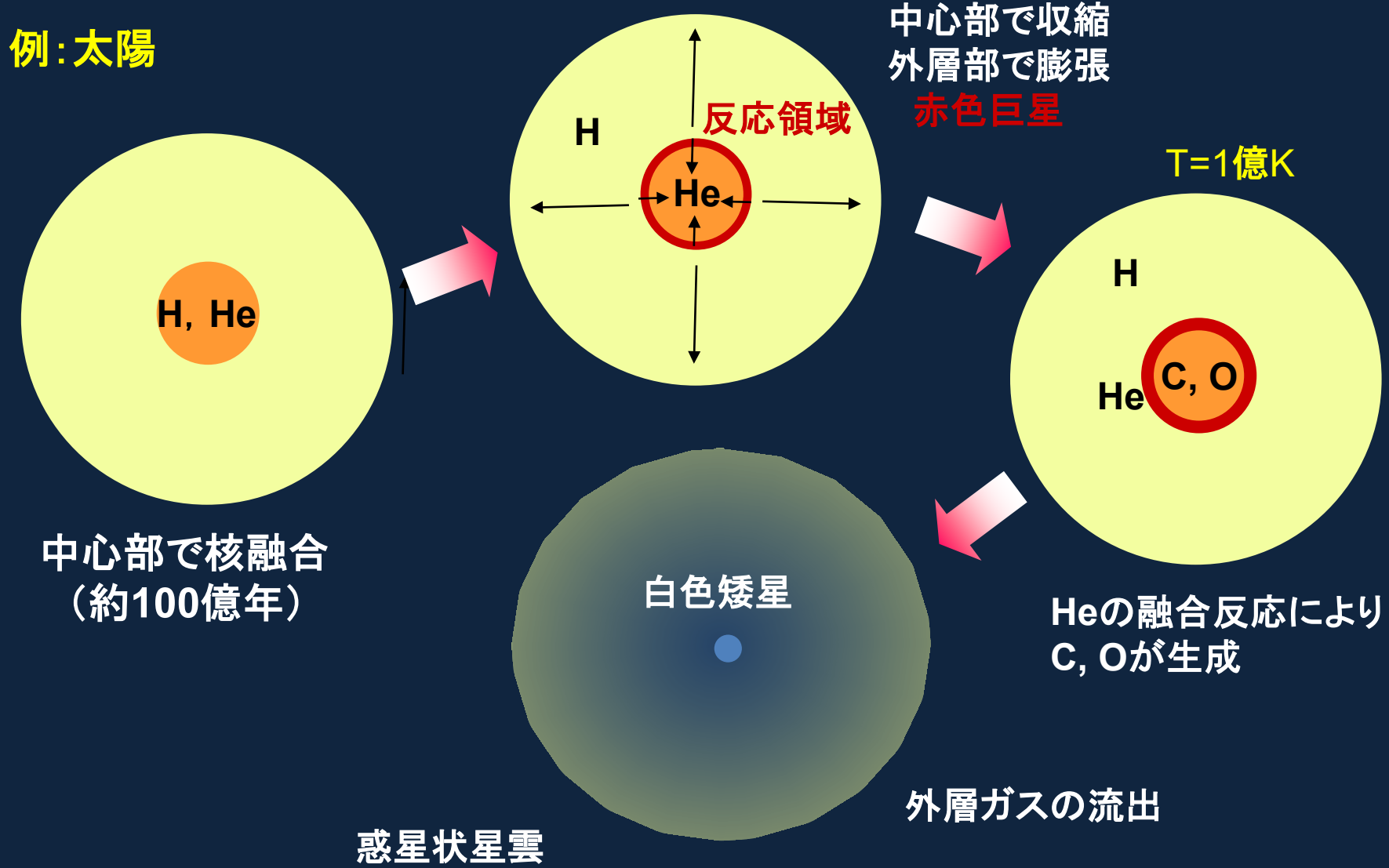
宇宙での元素合成サイクル



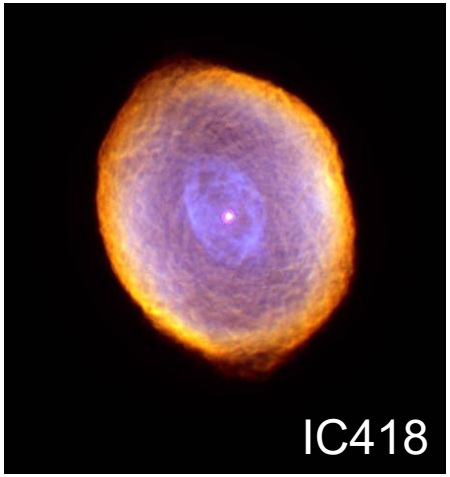
恒星の形成，進化

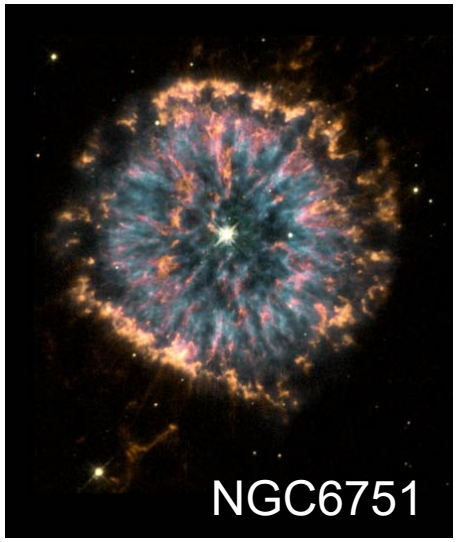


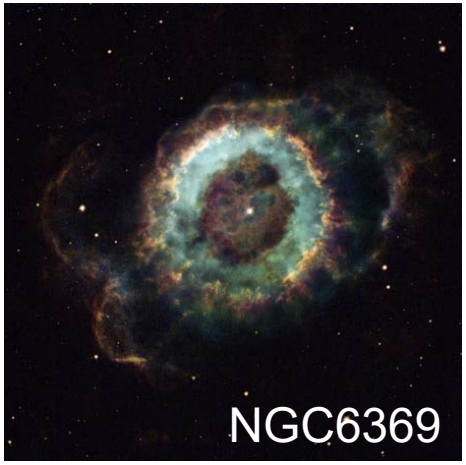
星の進化： 0.8Ms<M < 8Ms

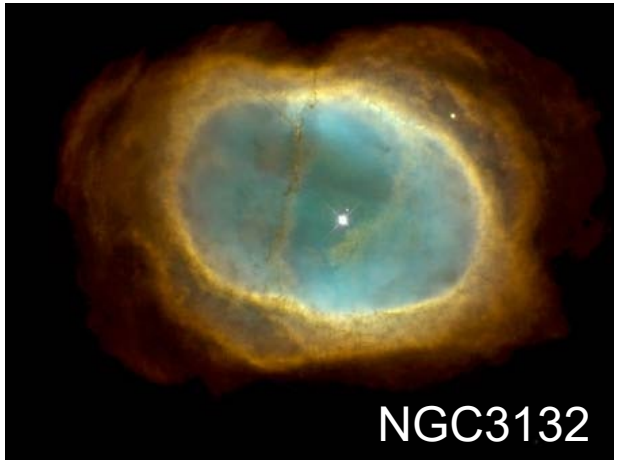


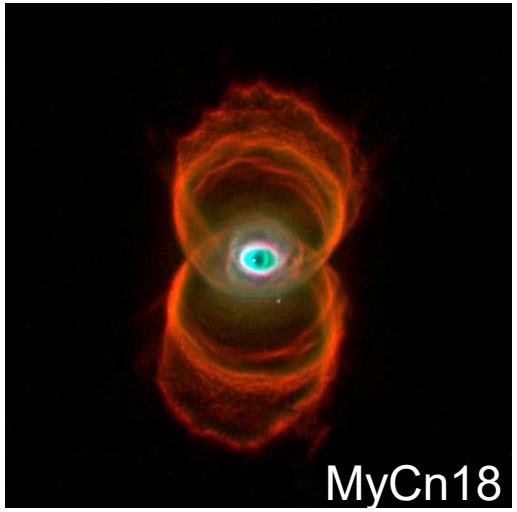
Hubble Space Telescopeが捉えた惑星状星雲 (sci.esa.int/hubble/gallery)



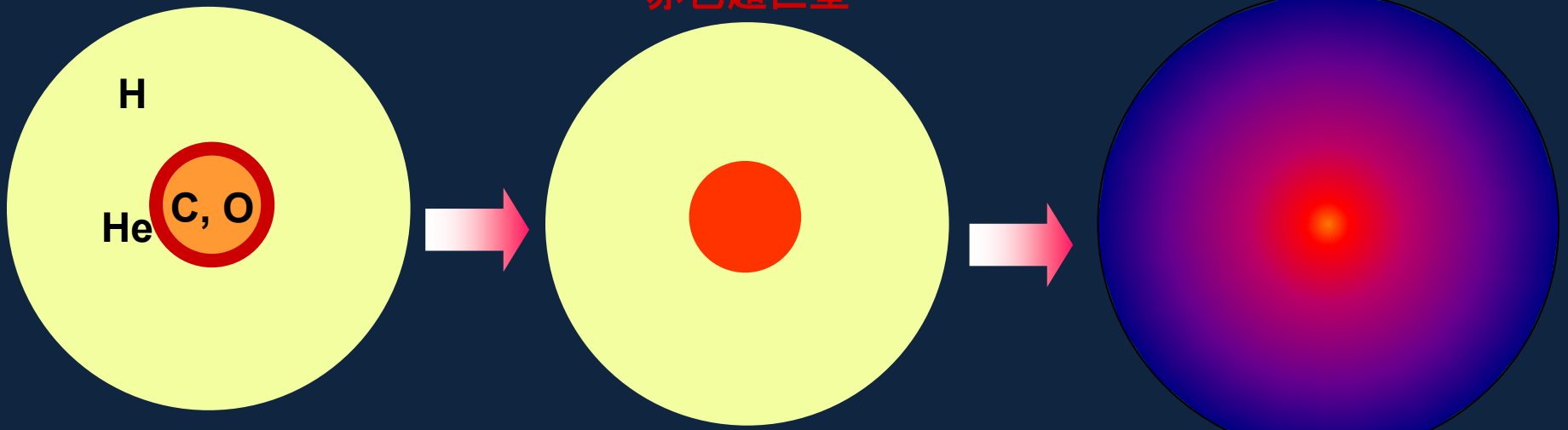








星の進化： M~10Ms の場合



赤色巨星

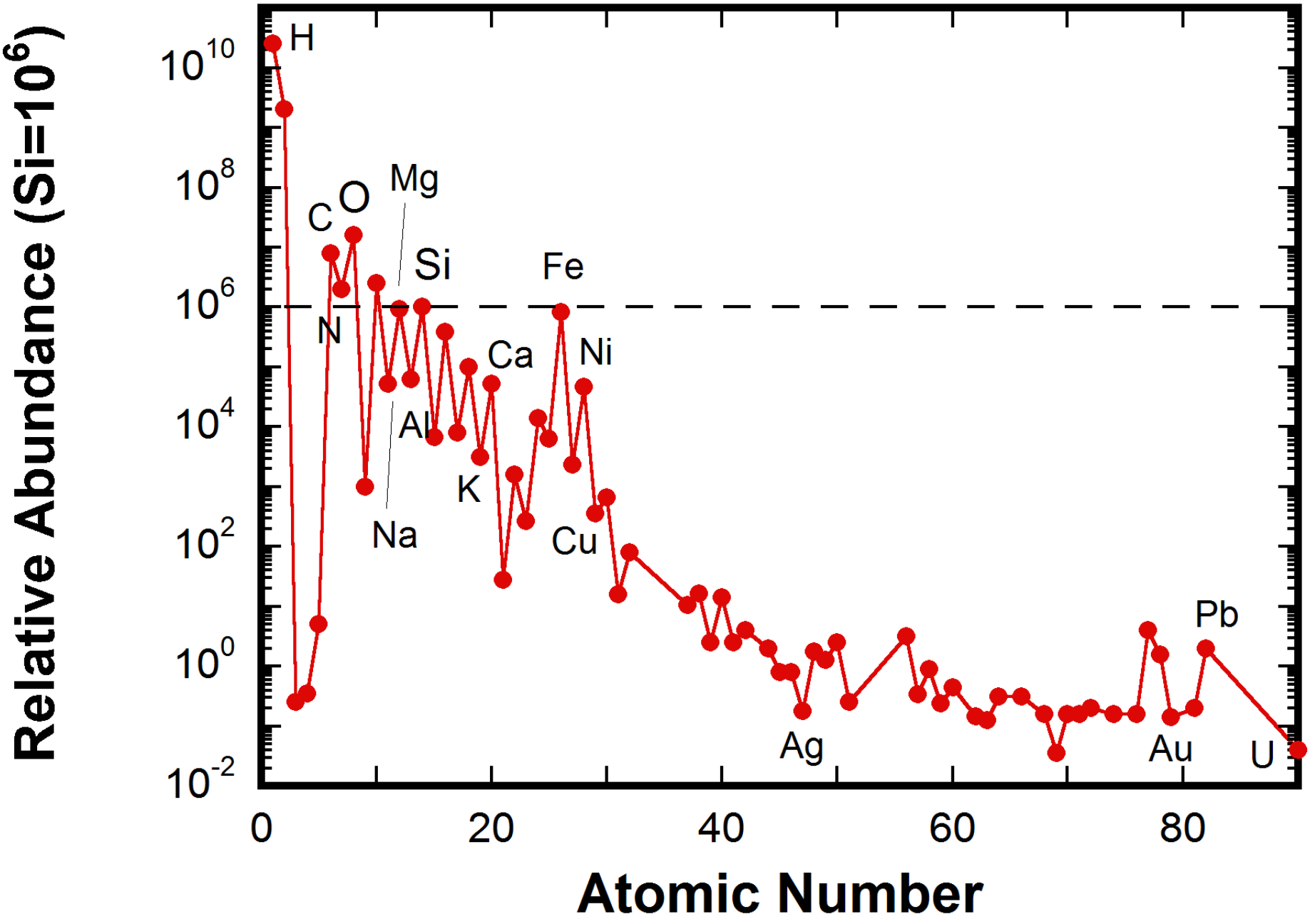
赤色超巨星

中心部でC, Oの融合反応が起き，Ne, Mg, Si, S, Ca, Feが合成される

超新星爆発

中心部が重力崩壊
Feよりも重い元素はこのプロセスでつくられる

中心は中性子星に


Relative Abundance (Si=10^6)
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
0
20
40
60
80
Atomic Number
H
C
O
N
Mg
Si
Na
Al
K
Ca
Fe
Ni
Cu
Ag
Au
Pb
U