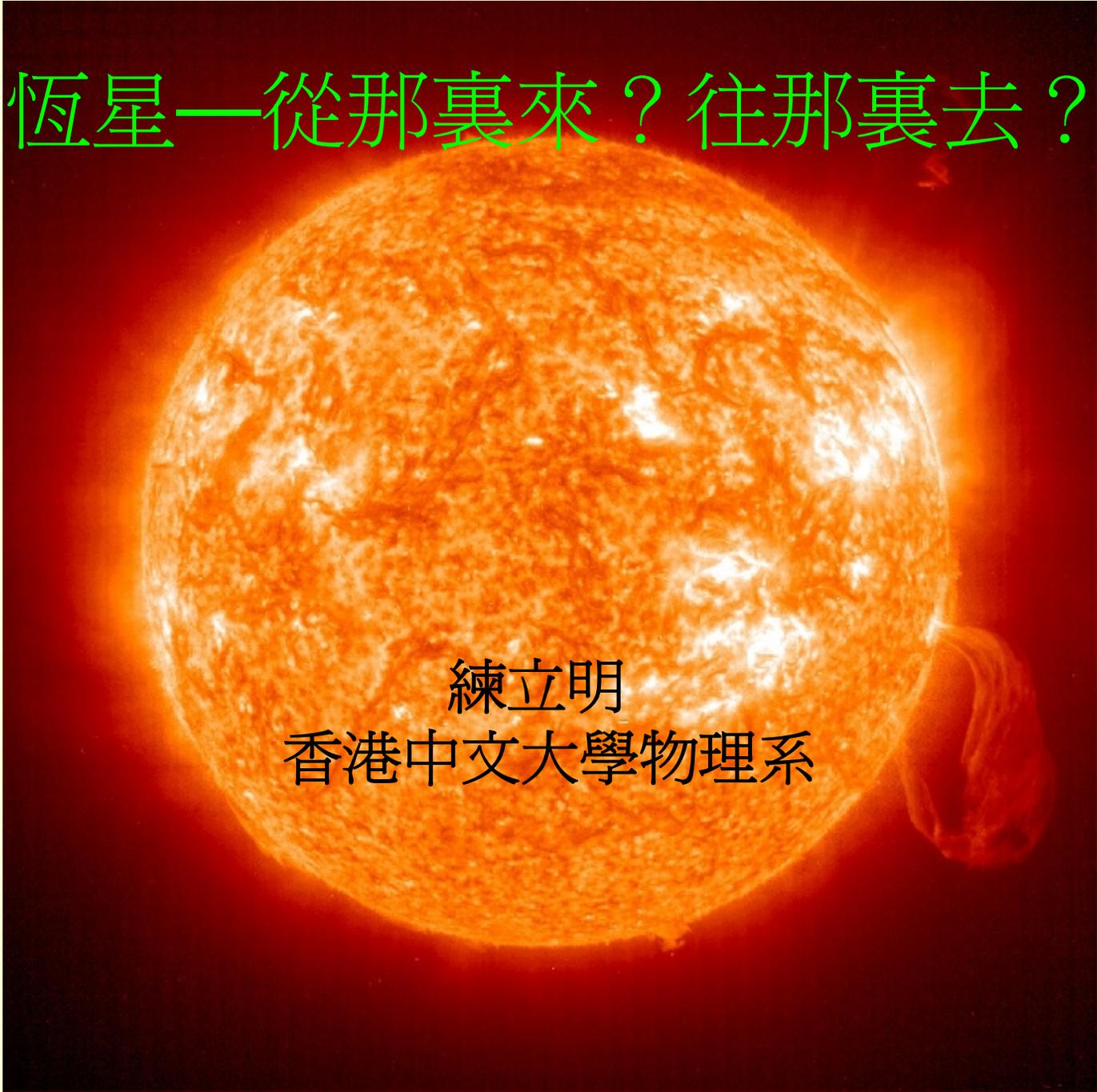
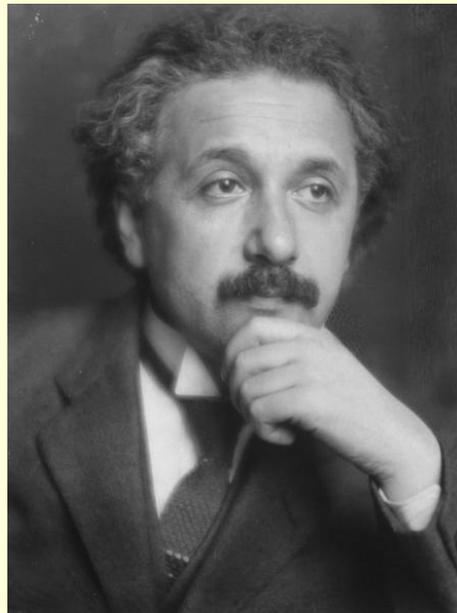
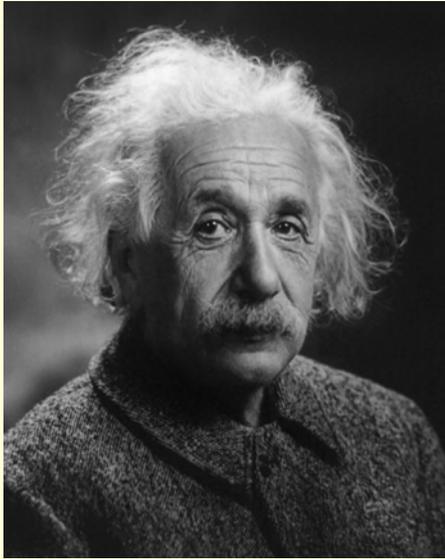


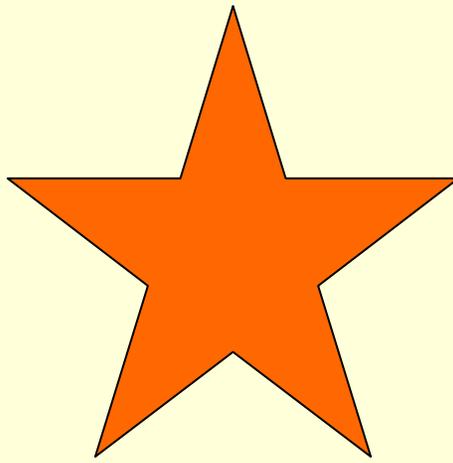
恆星—從那裏來？往那裏去？



練立明
香港中文大學物理系

人的一生

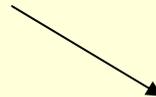




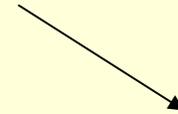
誕生



演化



死亡



?

星際物質

氣體，塵埃

(主要是氫氣“H”)



密度 ↑

星雲



馬頭星雲



??





玫瑰星雲





M78

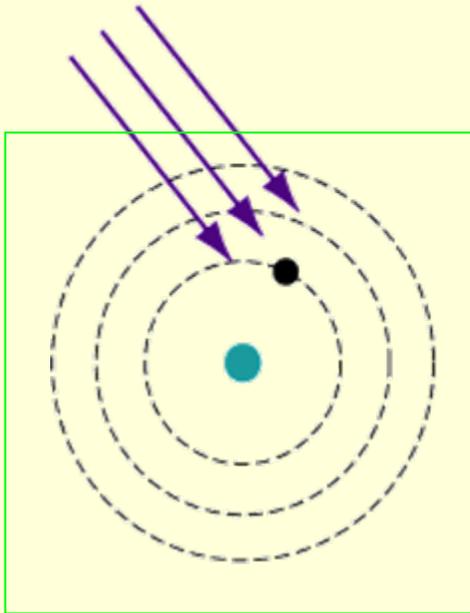


放射星雲

反射星雲

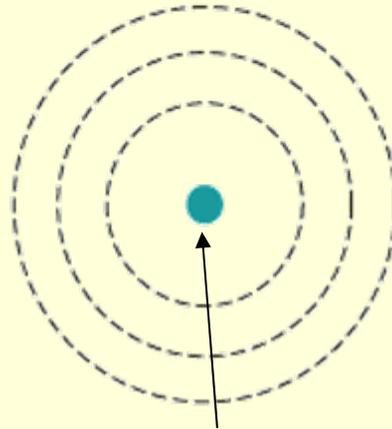
黑暗星雲



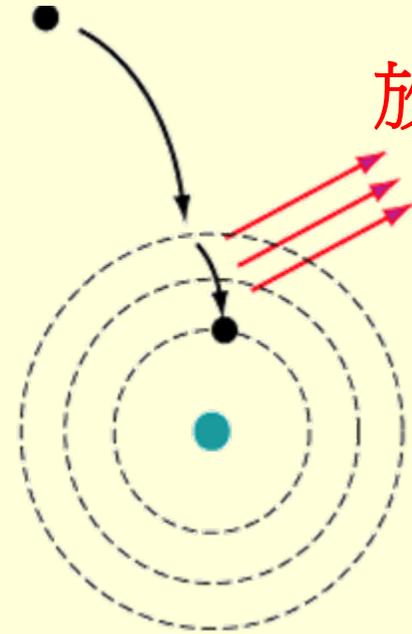


氫

電子



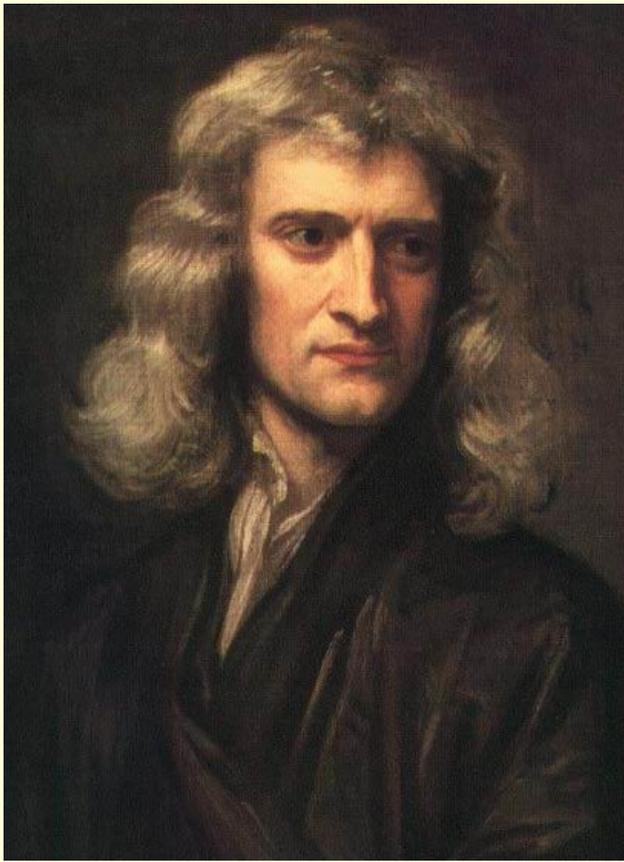
質子



放射 !!

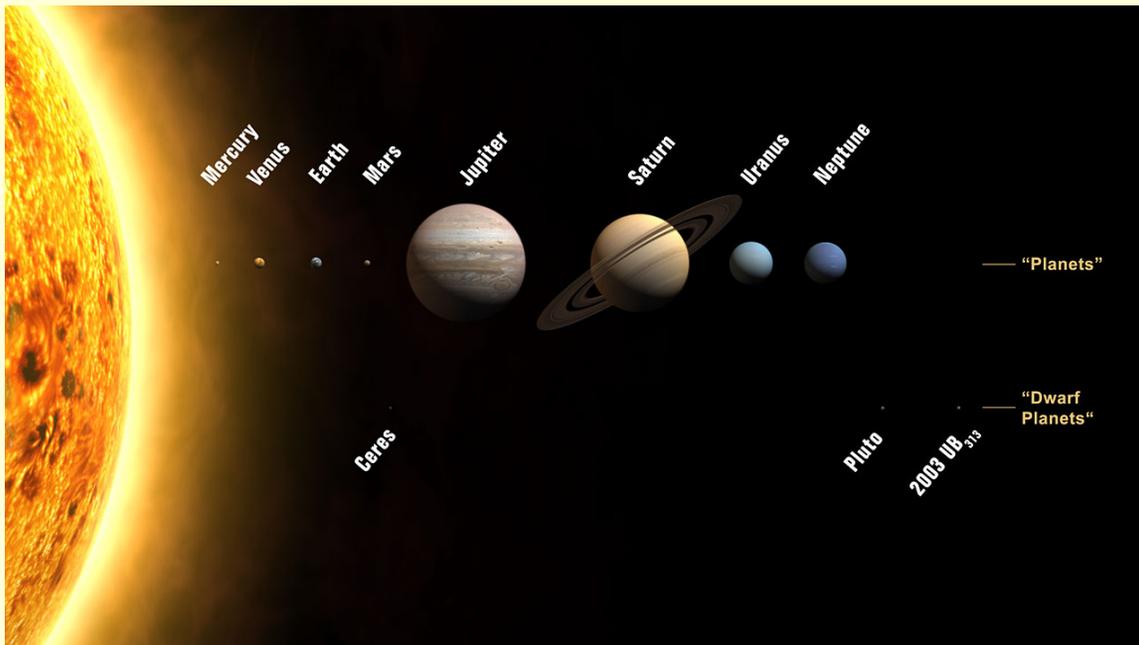
恆星的誕生

萬有引力



牛頓 (1642-1727)





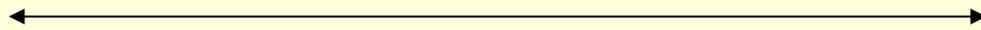
太陽系

神舟七號



潮汐

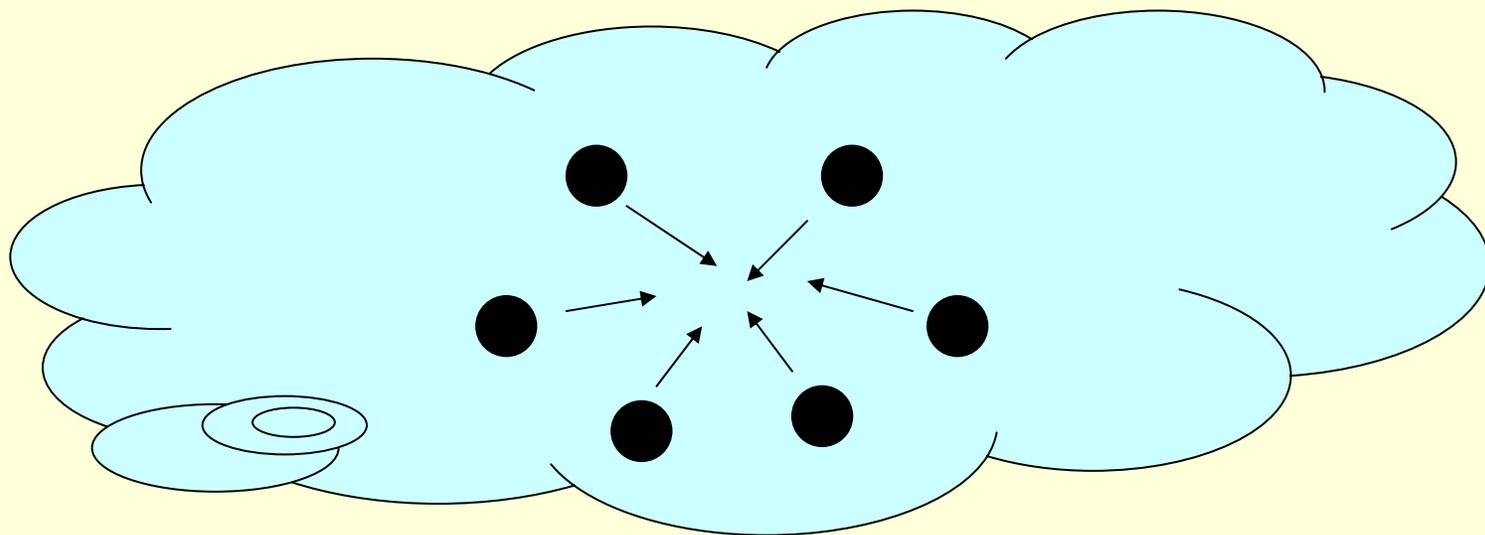




200 m 深

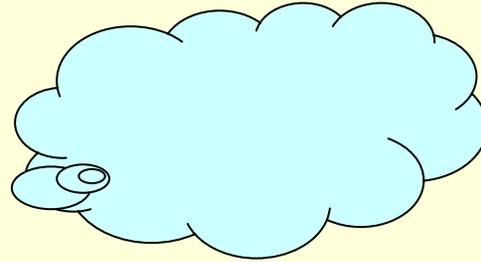
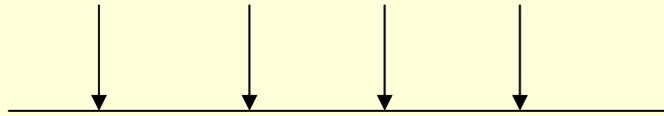
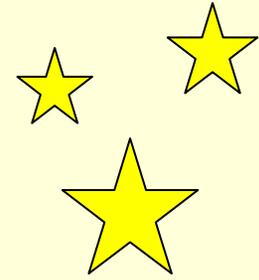
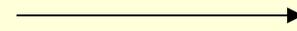
1.2 km

萬有引力 → 收縮 → 恆星 ??

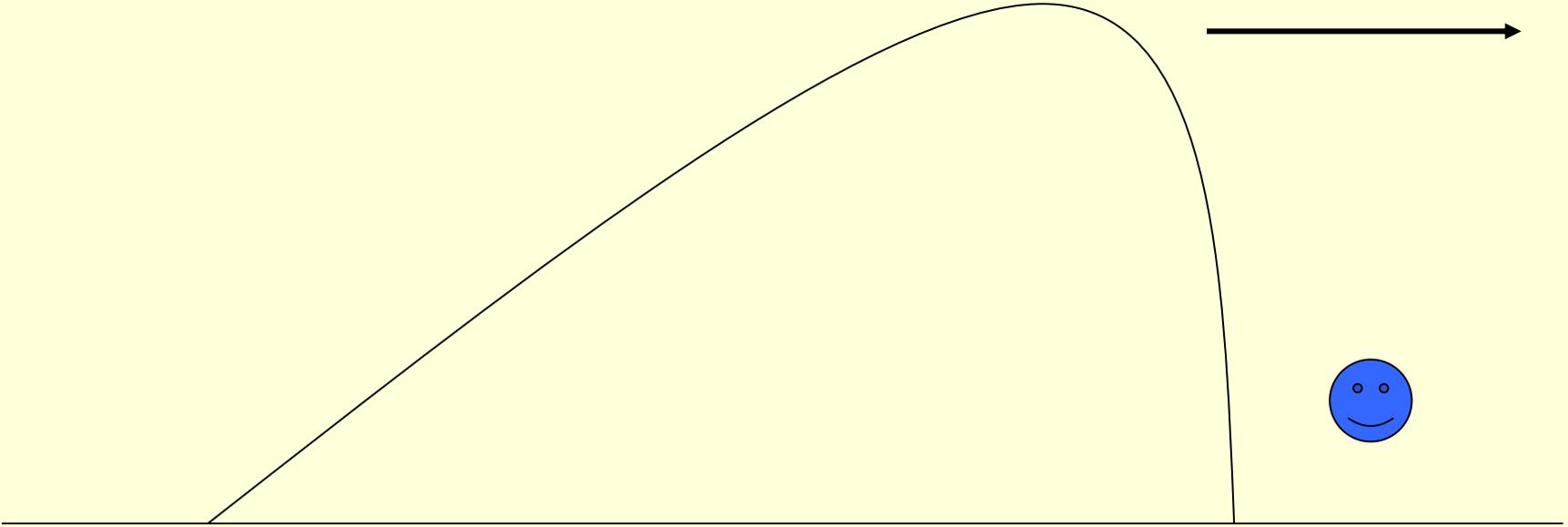


星雲

引力 + 激振波

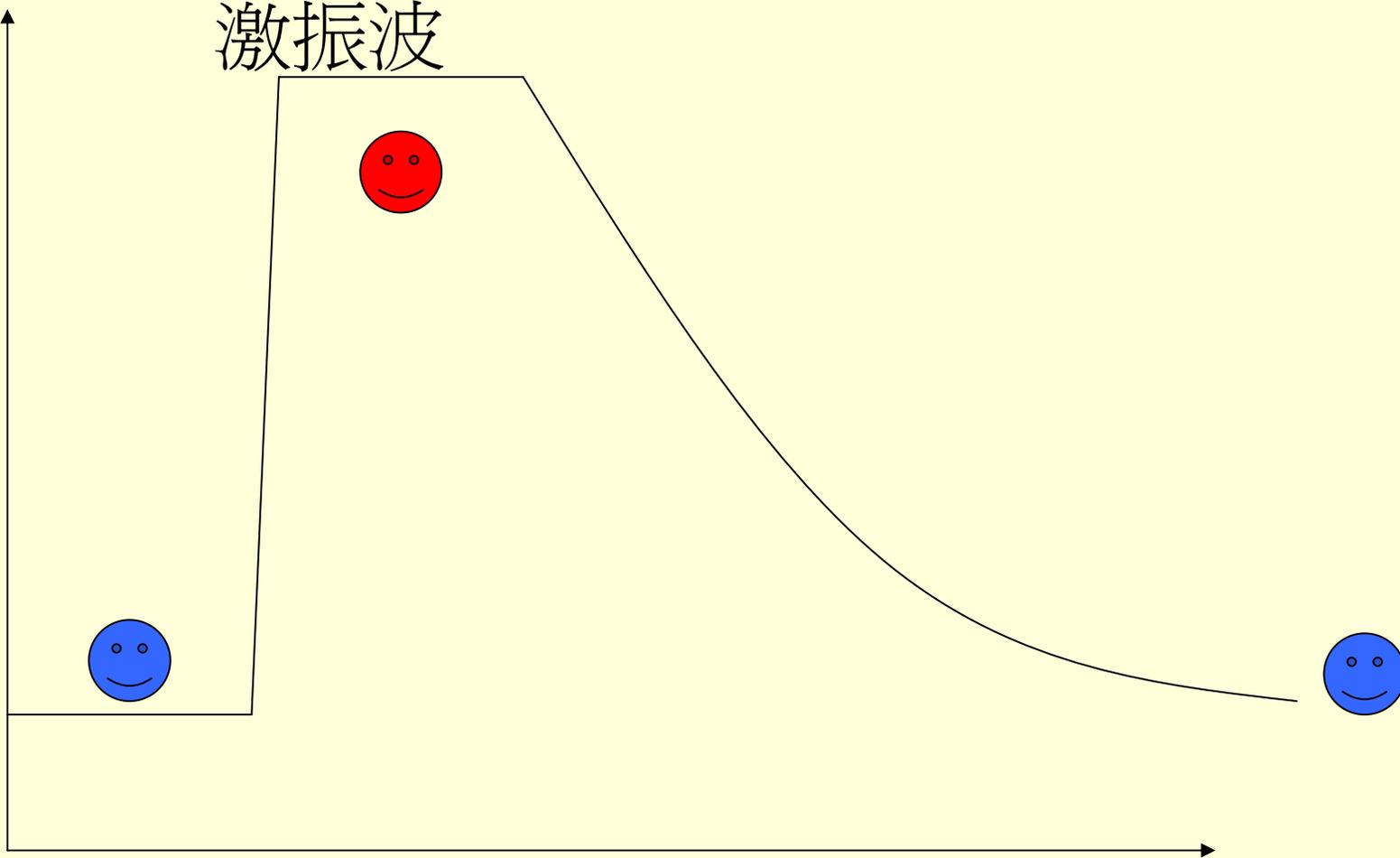


激振波？



壓力

激振波



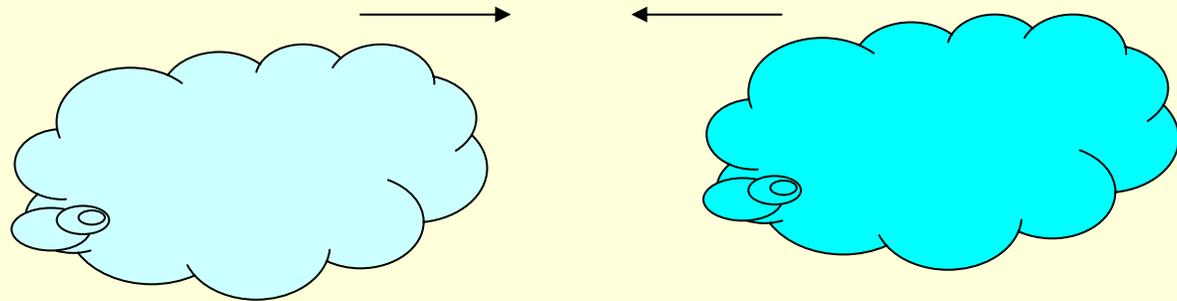
時間

激振波來源：

超新星爆炸



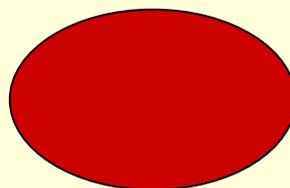
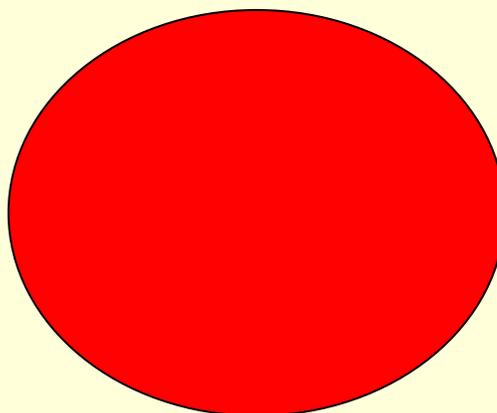
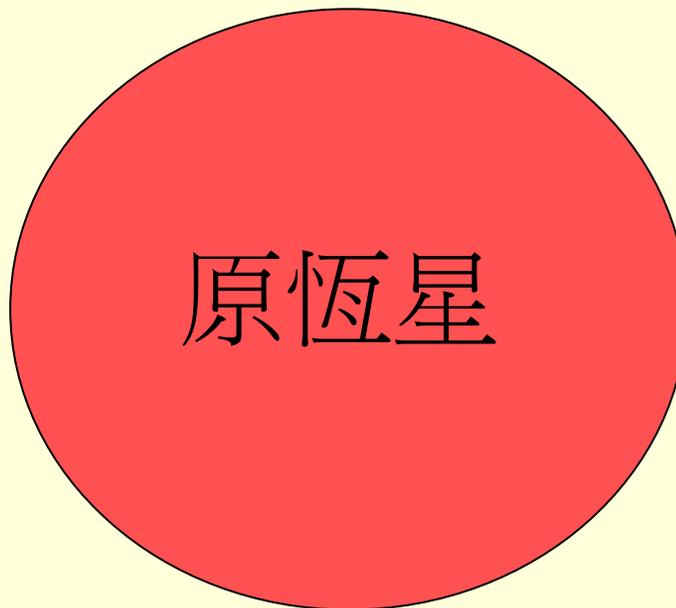
星雲的撞擊



密度 ↑

溫度 ↑

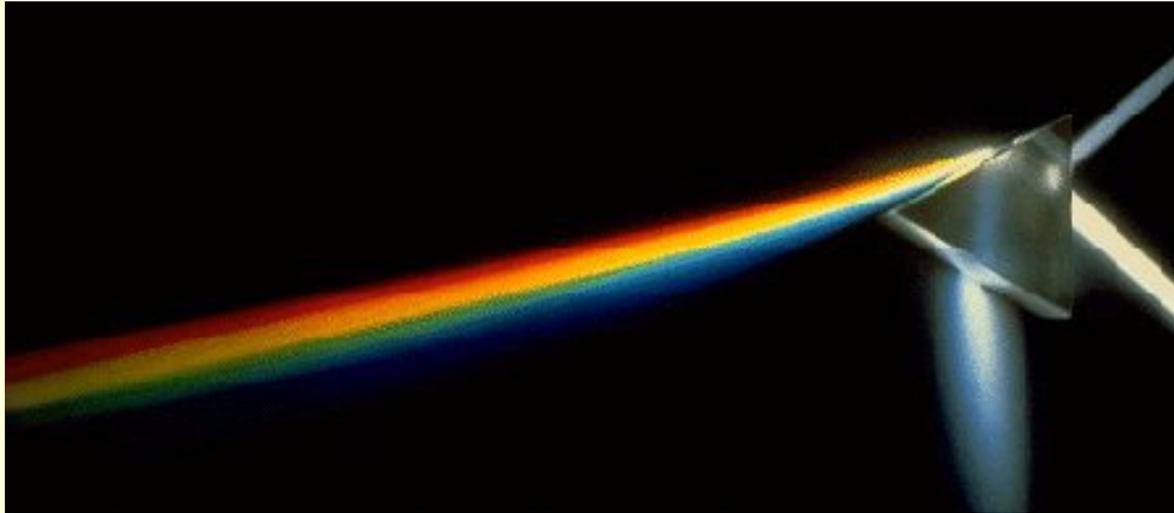
壓力 ↑



紅外線輻射

??

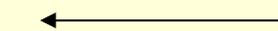




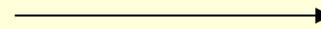
伽瑪射線，X光，紫外光



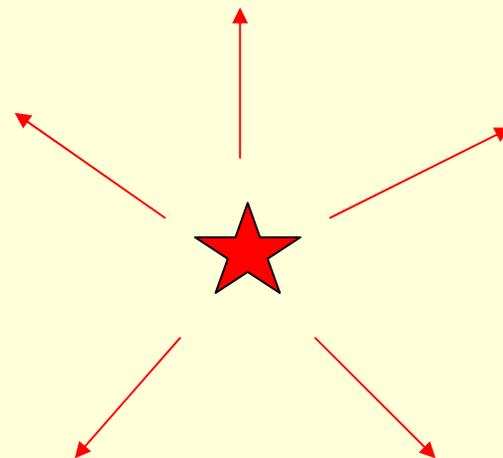
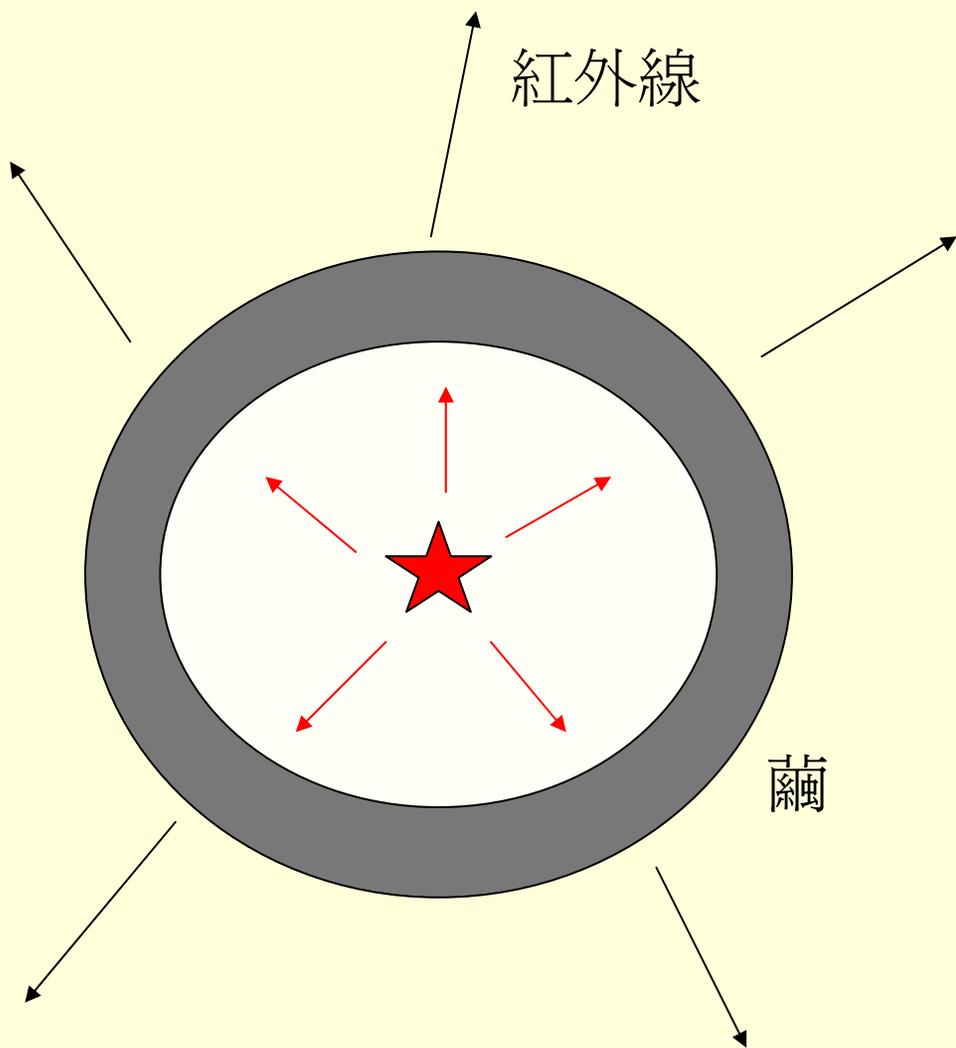
紅外線，微波，無線電波

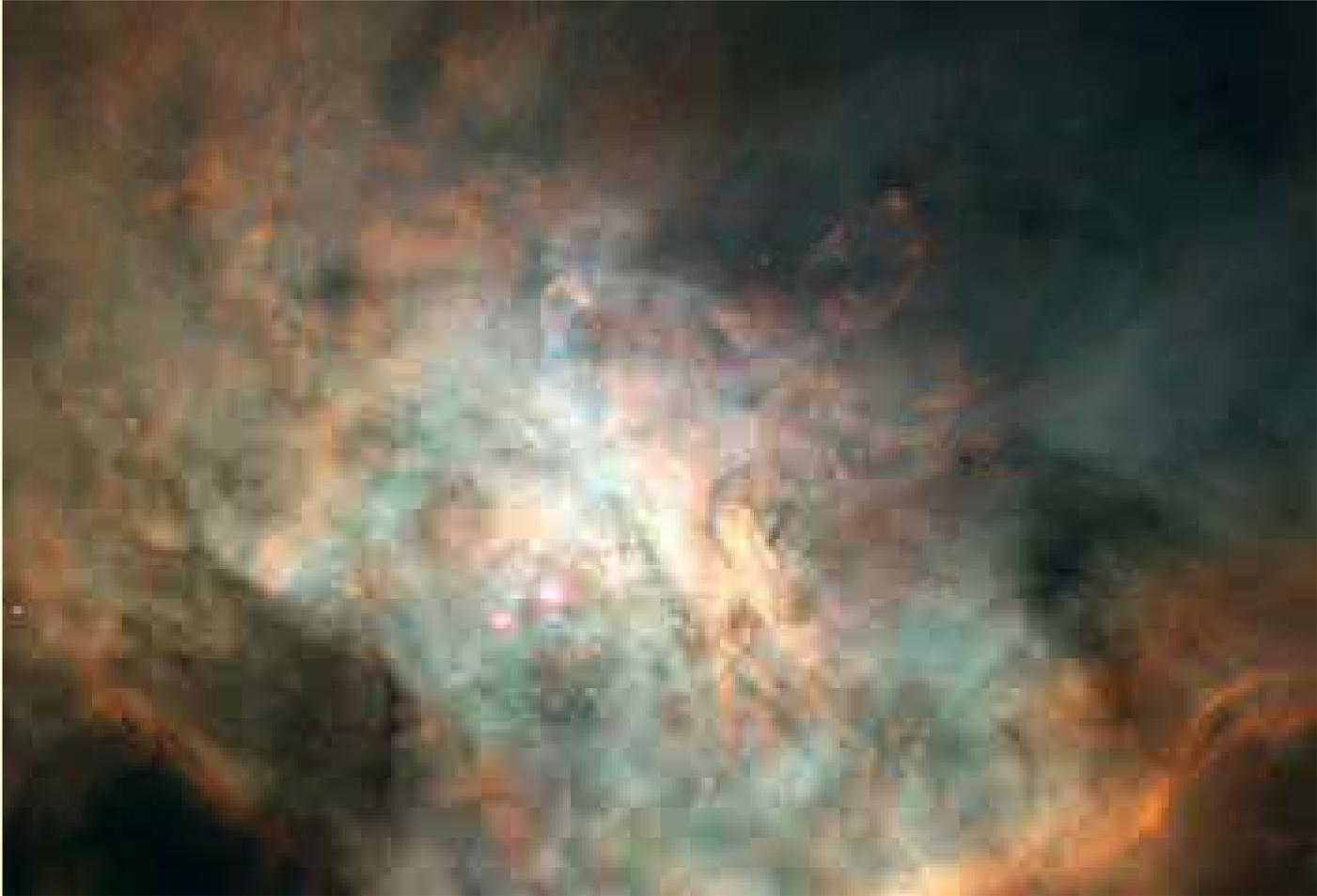
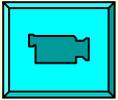


能量 ↑

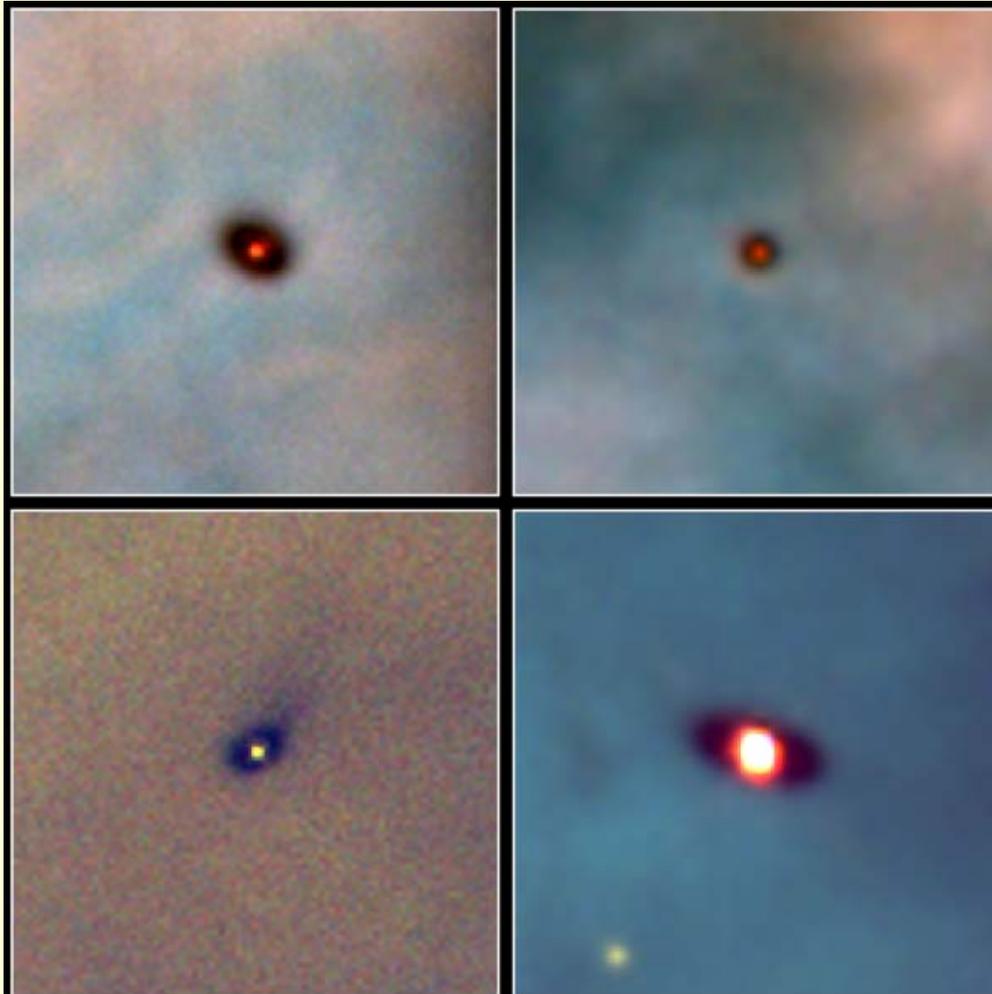


能量 ↓





原始行星盤



**Protoplanetary Disks
Orion Nebula**

HST · WFPC2

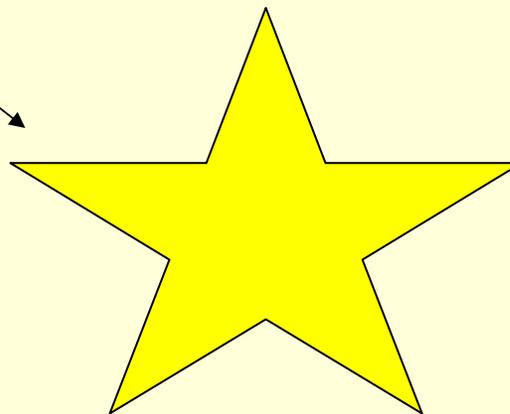
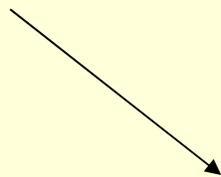
PRC95-45b · ST ScI OPO · November 20, 1995

M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

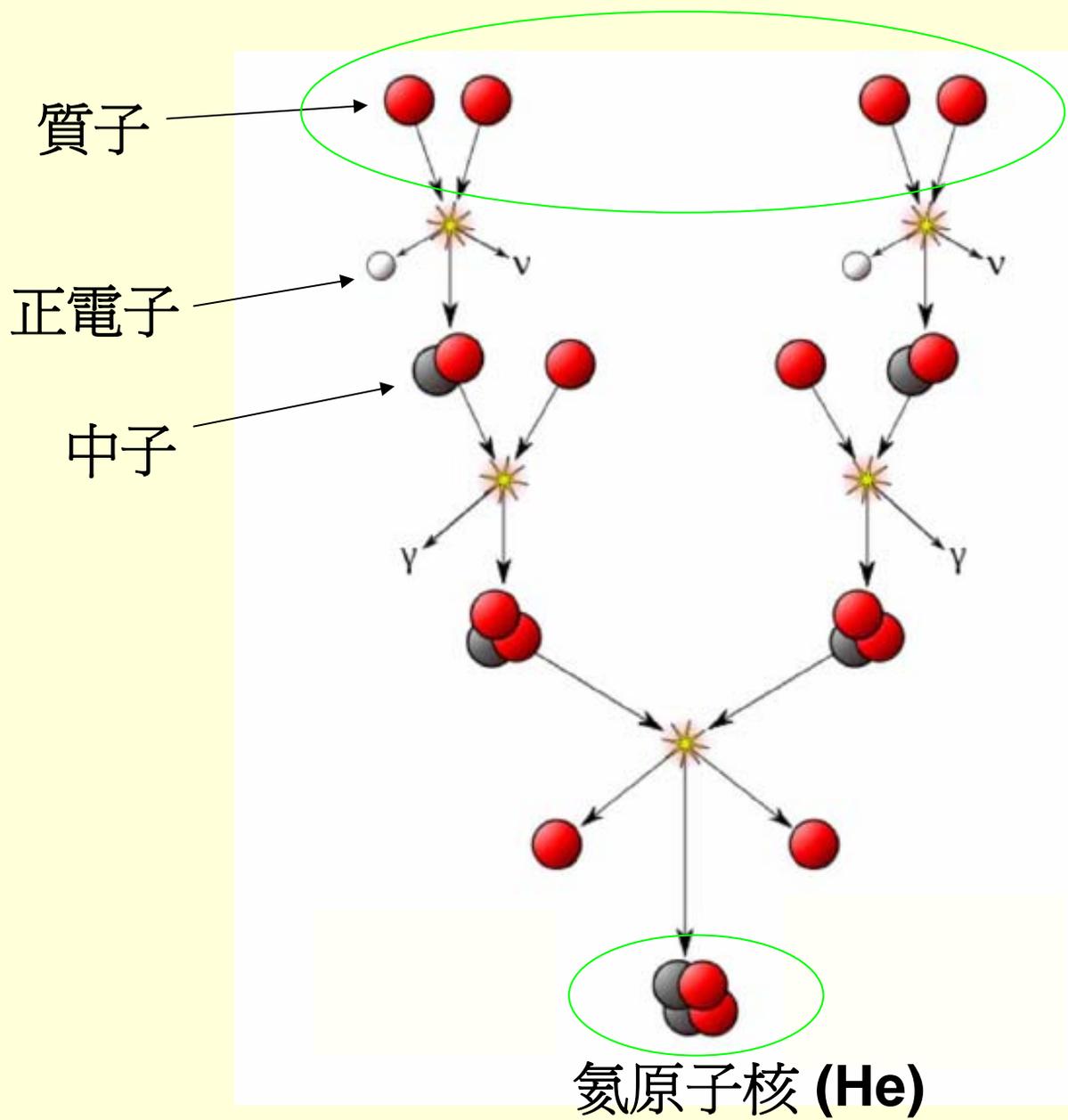
恆星的演化



“如果”質量足夠大



溫度, 密度足夠高 → 核反應 (??)

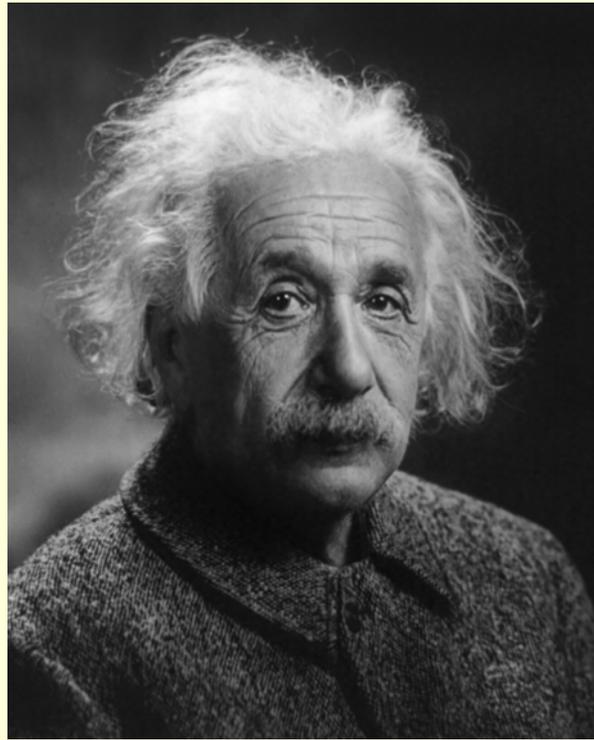




$$4 M(\text{質子}) > M(\text{氦})$$

↓

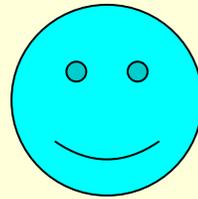
能量



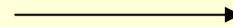
愛因斯坦
(1879-1955)

$$E = M c^2$$

能量 = 質量



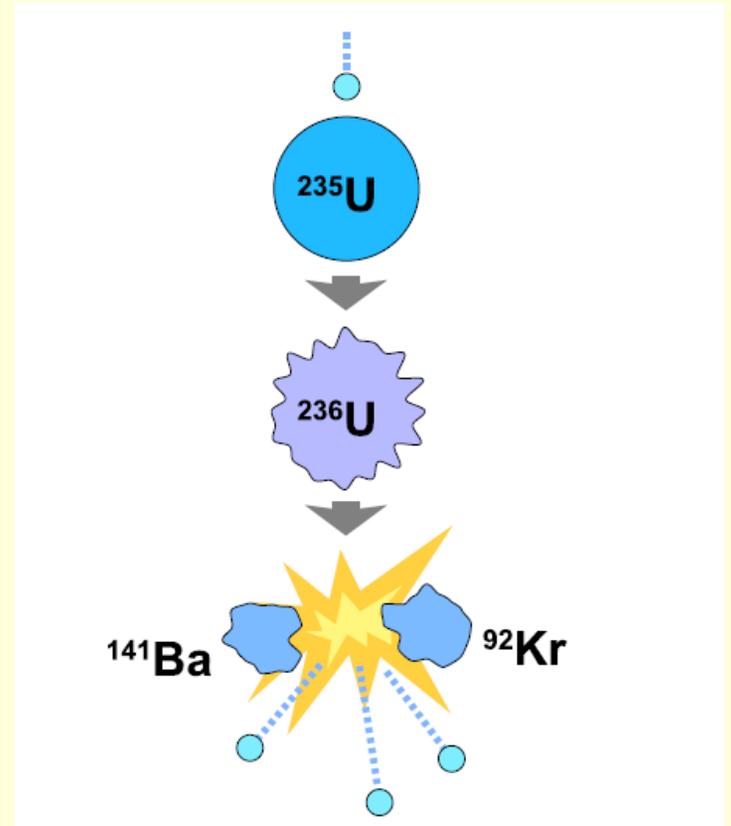
50 kg



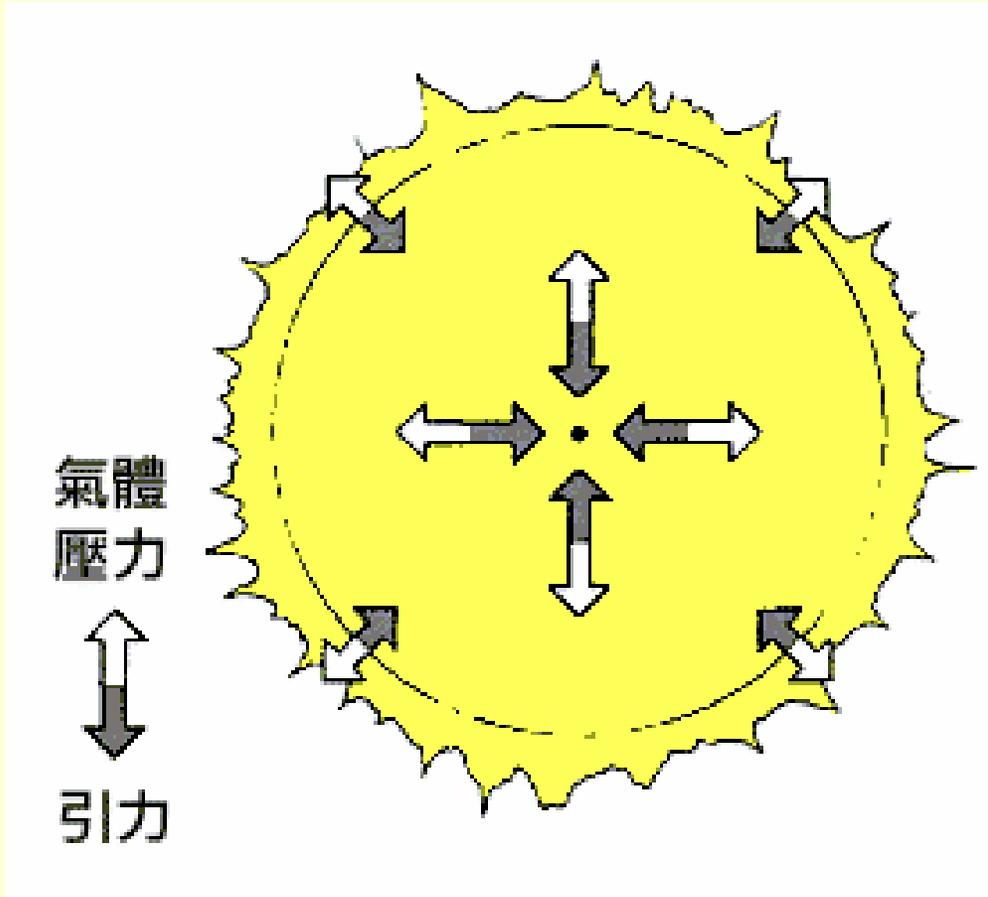
100 W

10 億年 !!

核裂變



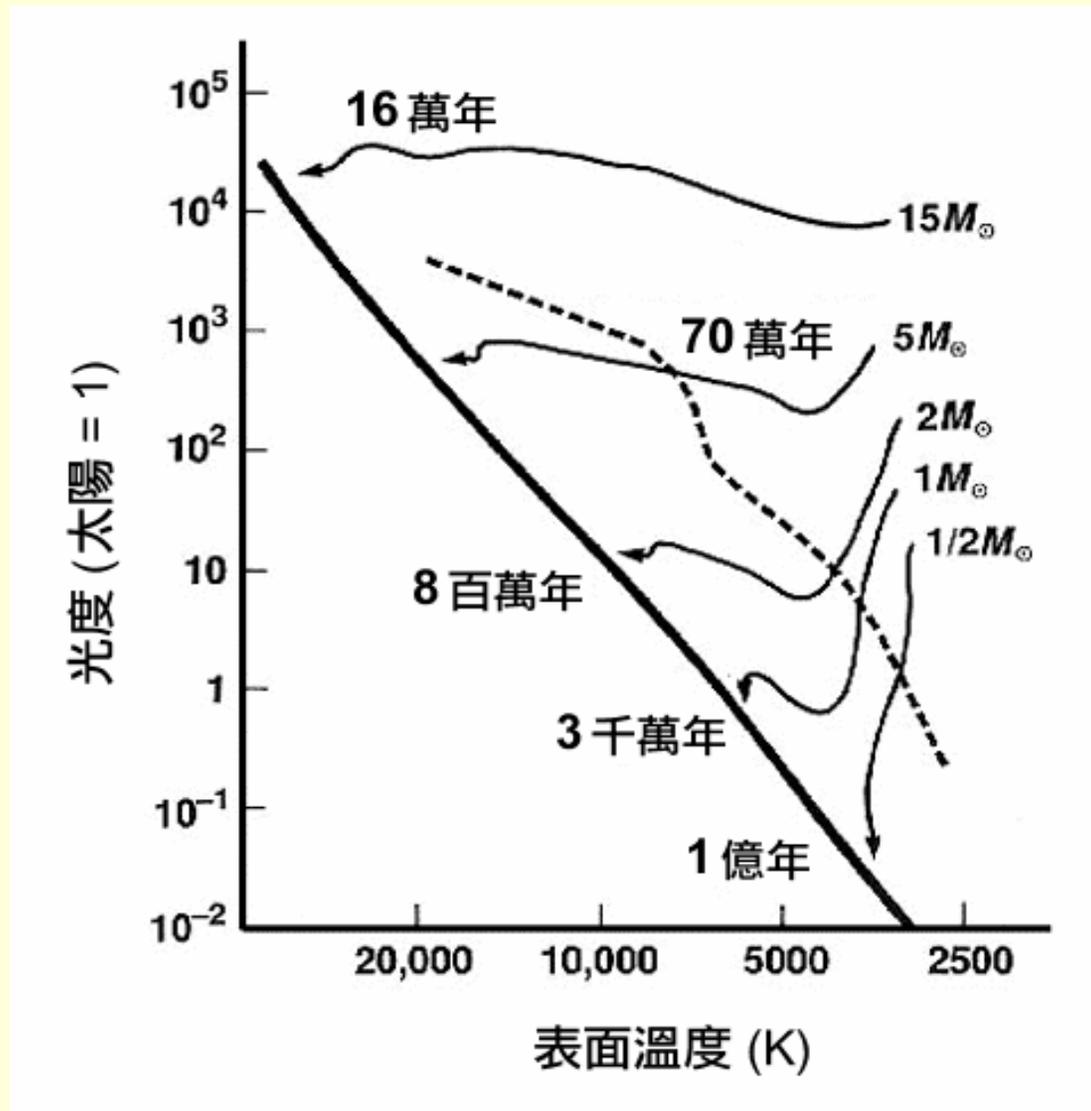
核聚變 → 能量 → 溫度，壓力 ↑



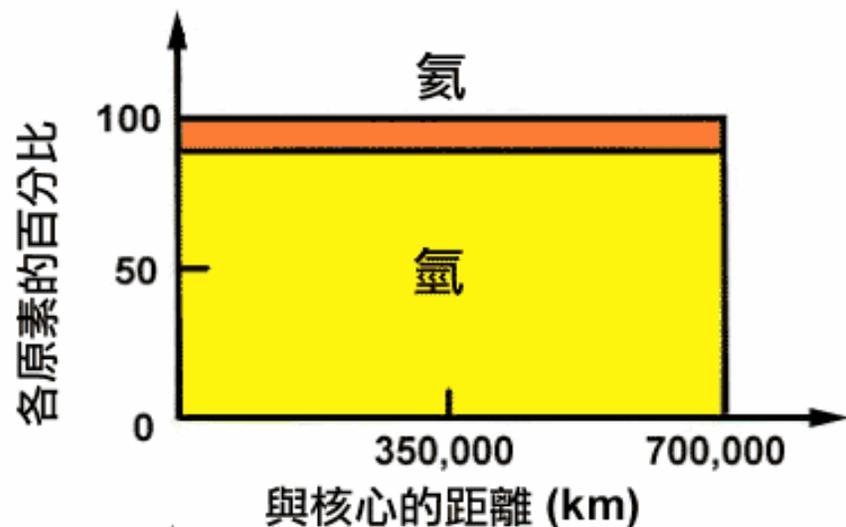
誕生了!!

主序星

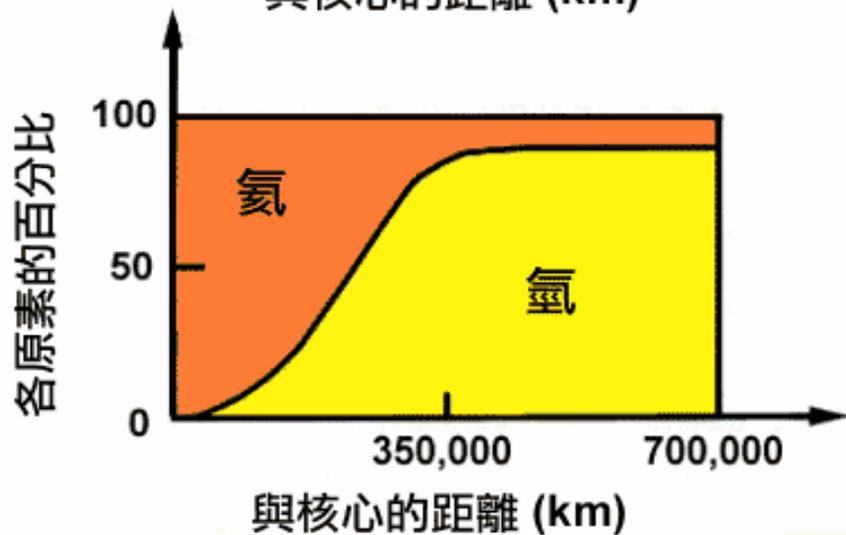
原恆星 → 主序星的時間



核聚變：氫 (H) \rightarrow 氦 (He)



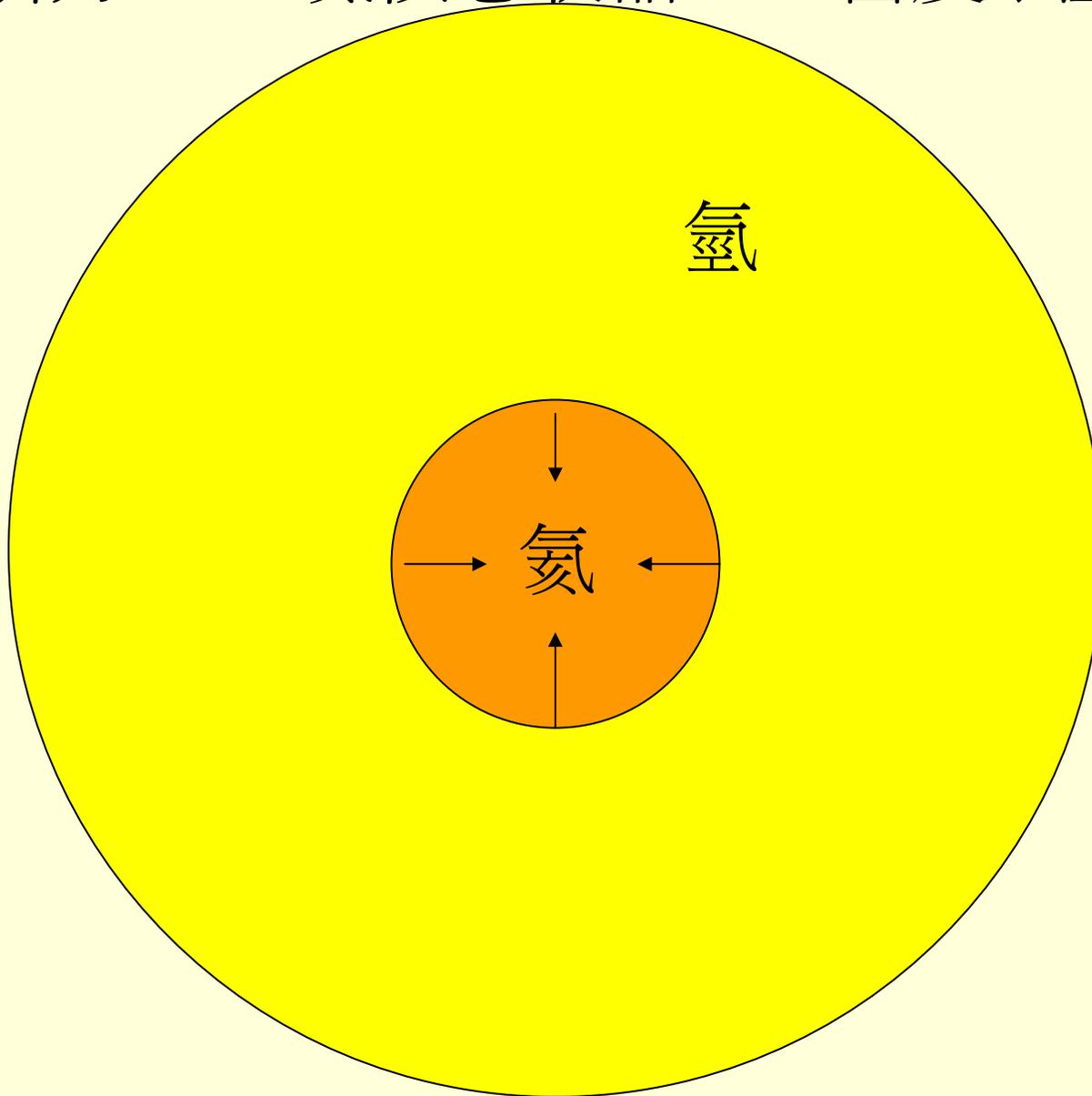
太陽誕生時

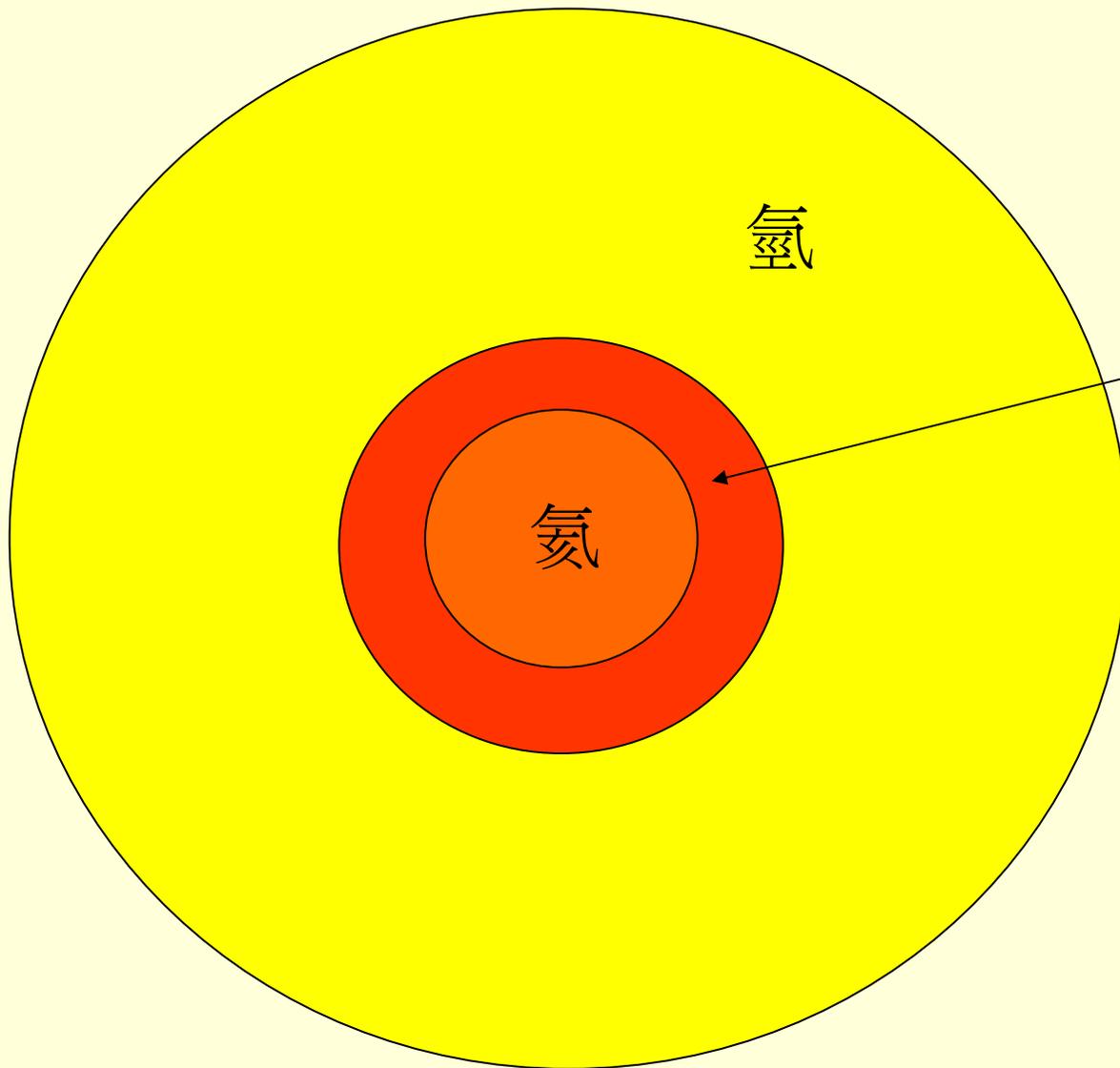


現時歲數 ~ 50億年

100億歲時

引力 \rightarrow 氦核心收縮 \rightarrow 密度, 溫度 \uparrow



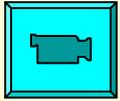


溫度足夠高
氫 → 氦

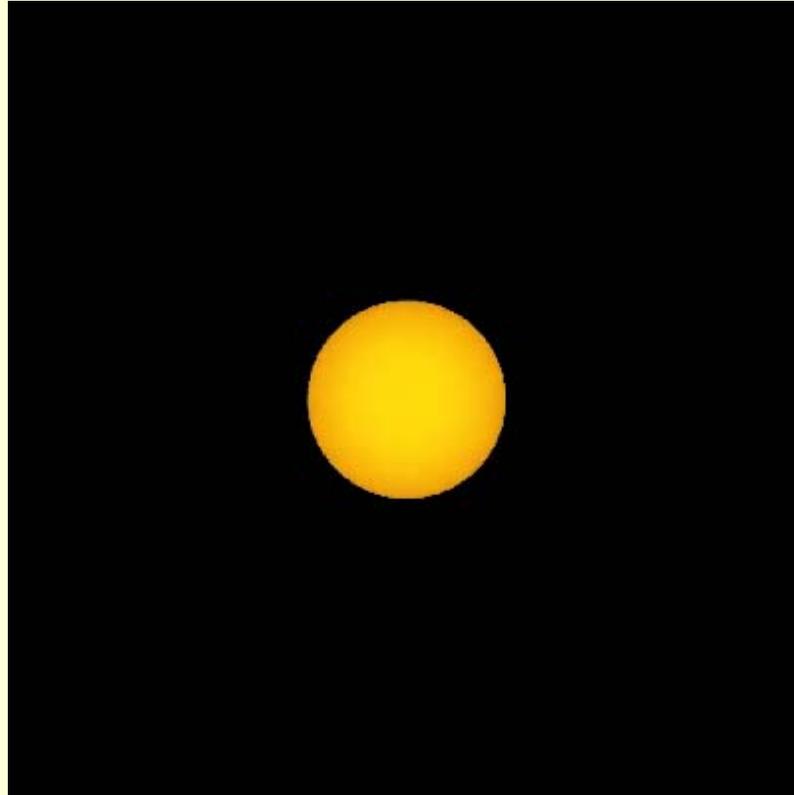
溫度，壓力 ↑



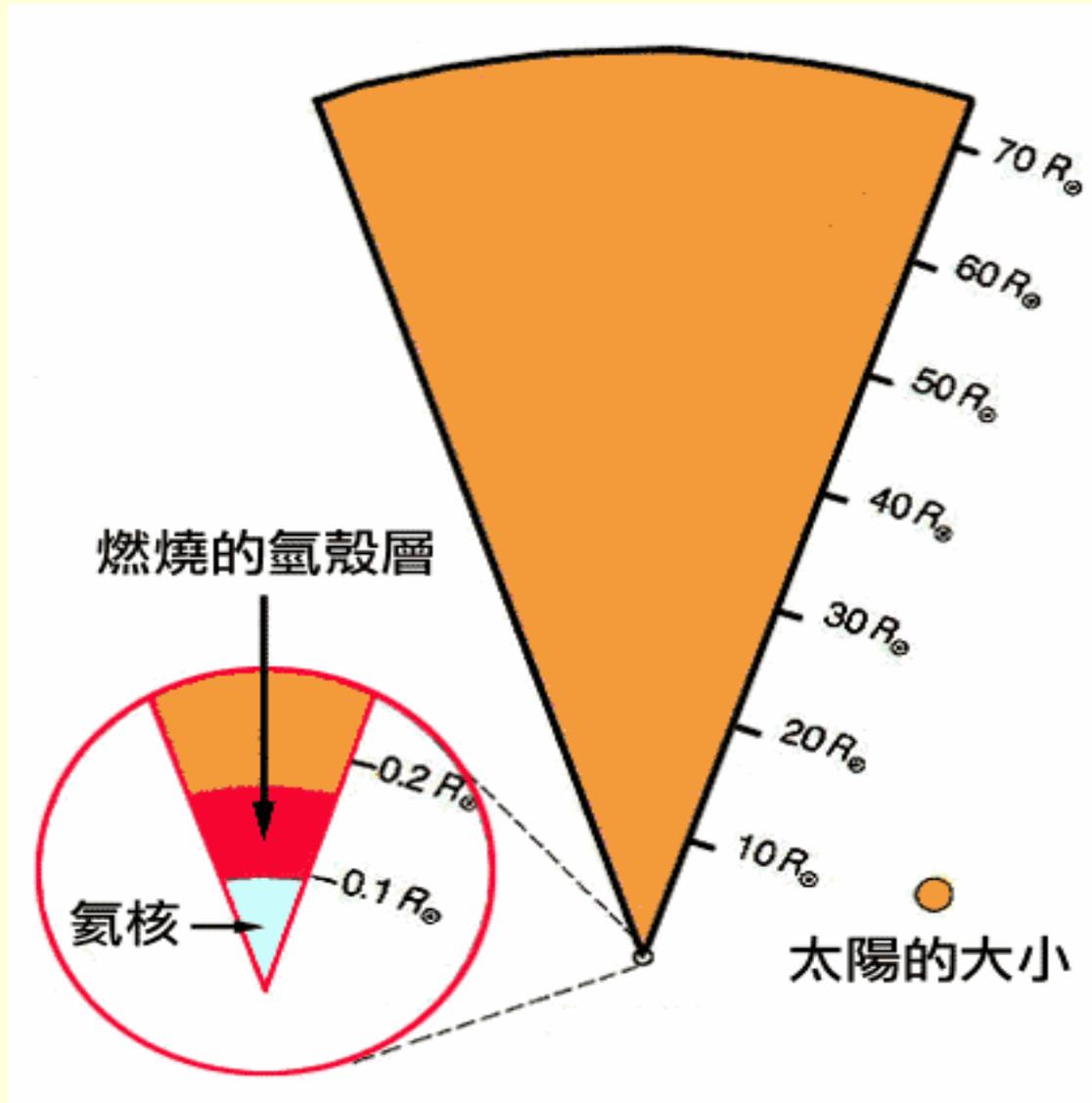
外層膨脹



紅巨星



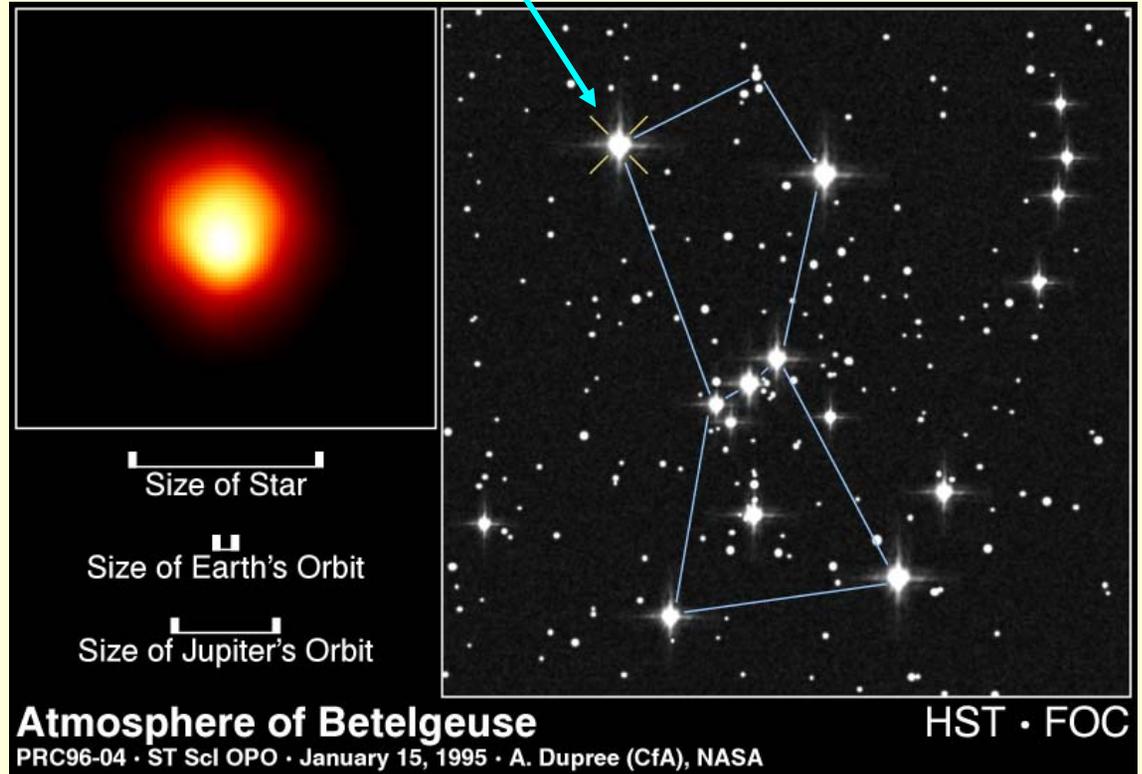
5個太陽質量的紅巨星

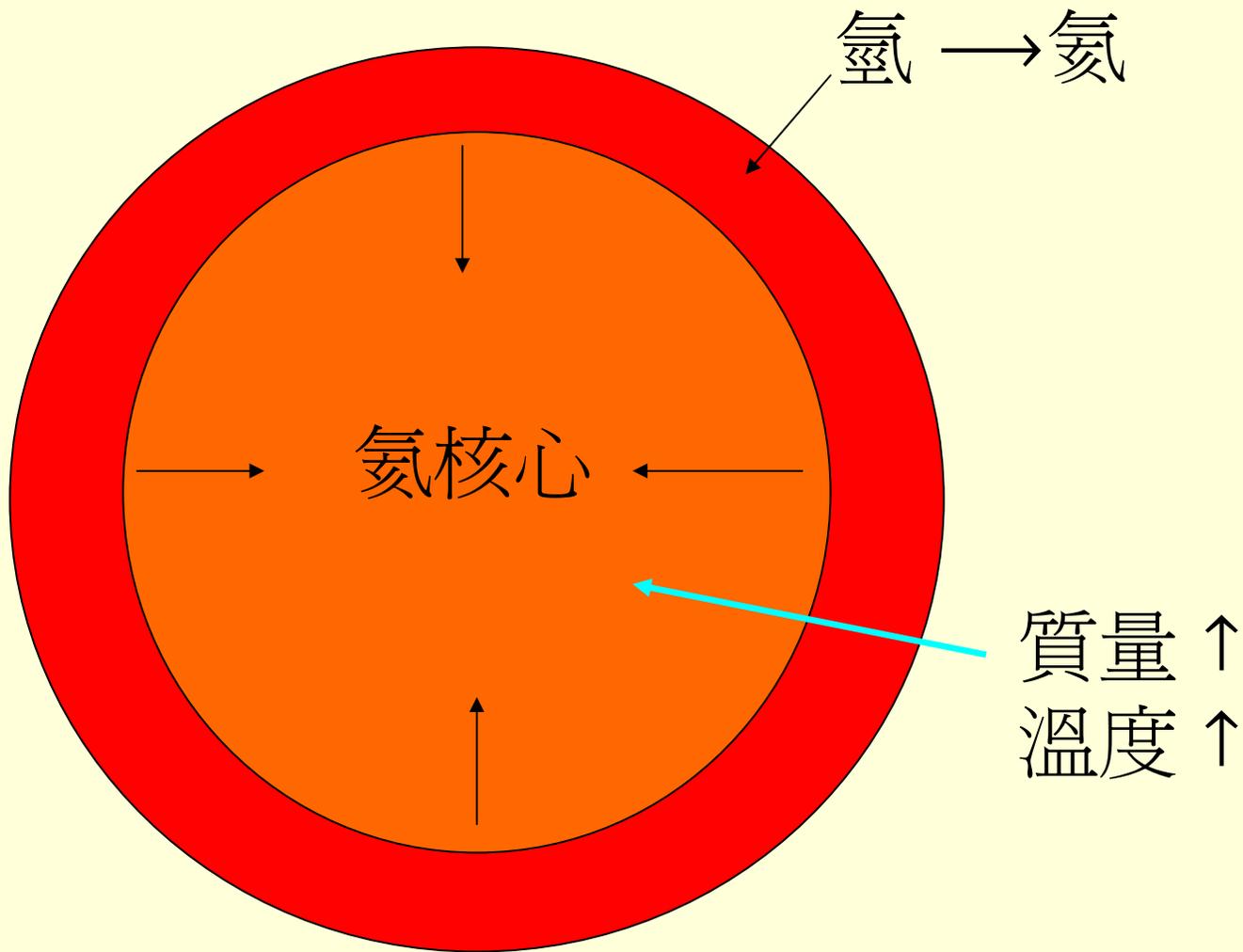


獵戶座內的紅巨星 (Betelgeuse)

20個太陽質量

半徑 ~ 太陽1000倍





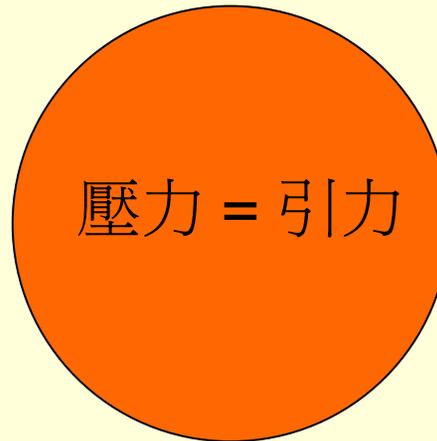
溫度 ~ 1 億度: 3個氦原子核 → 碳原子核

3個氦原子核 → 碳原子核



能量 → 溫度，壓力 ↑

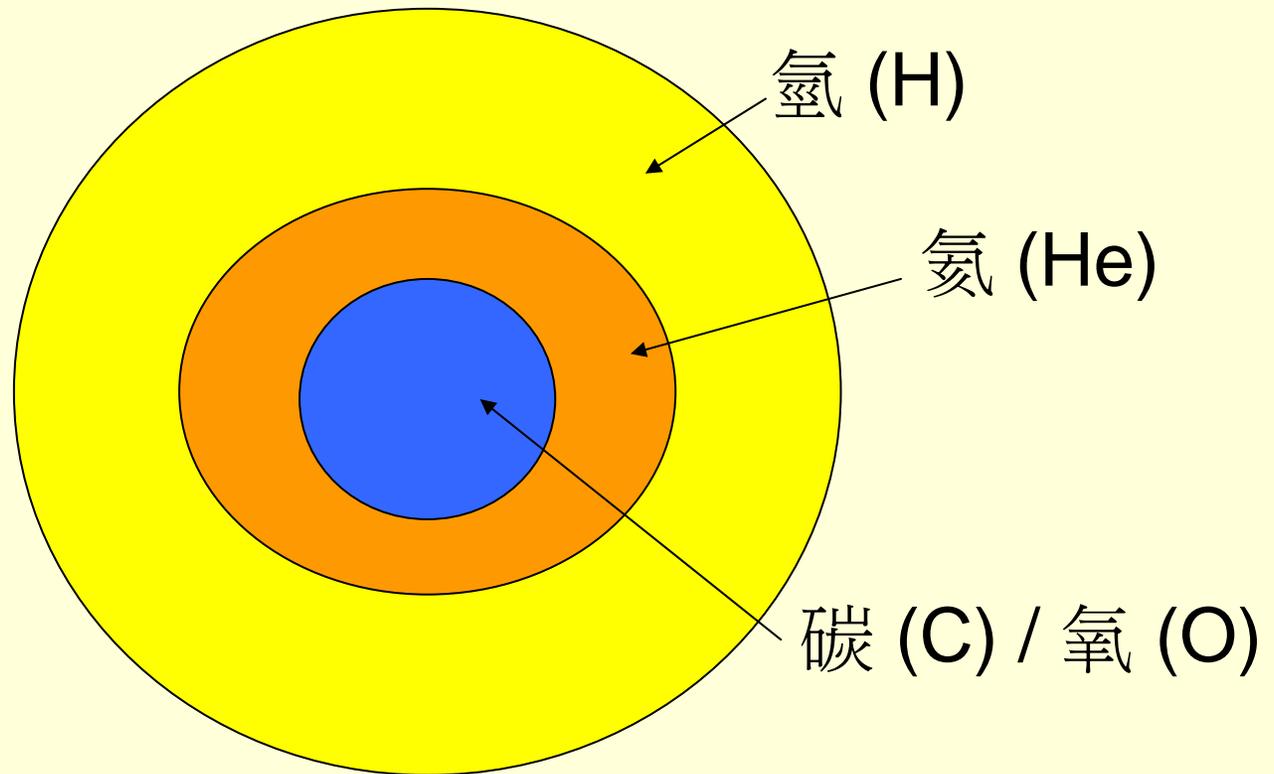
氦核心



恆星之死

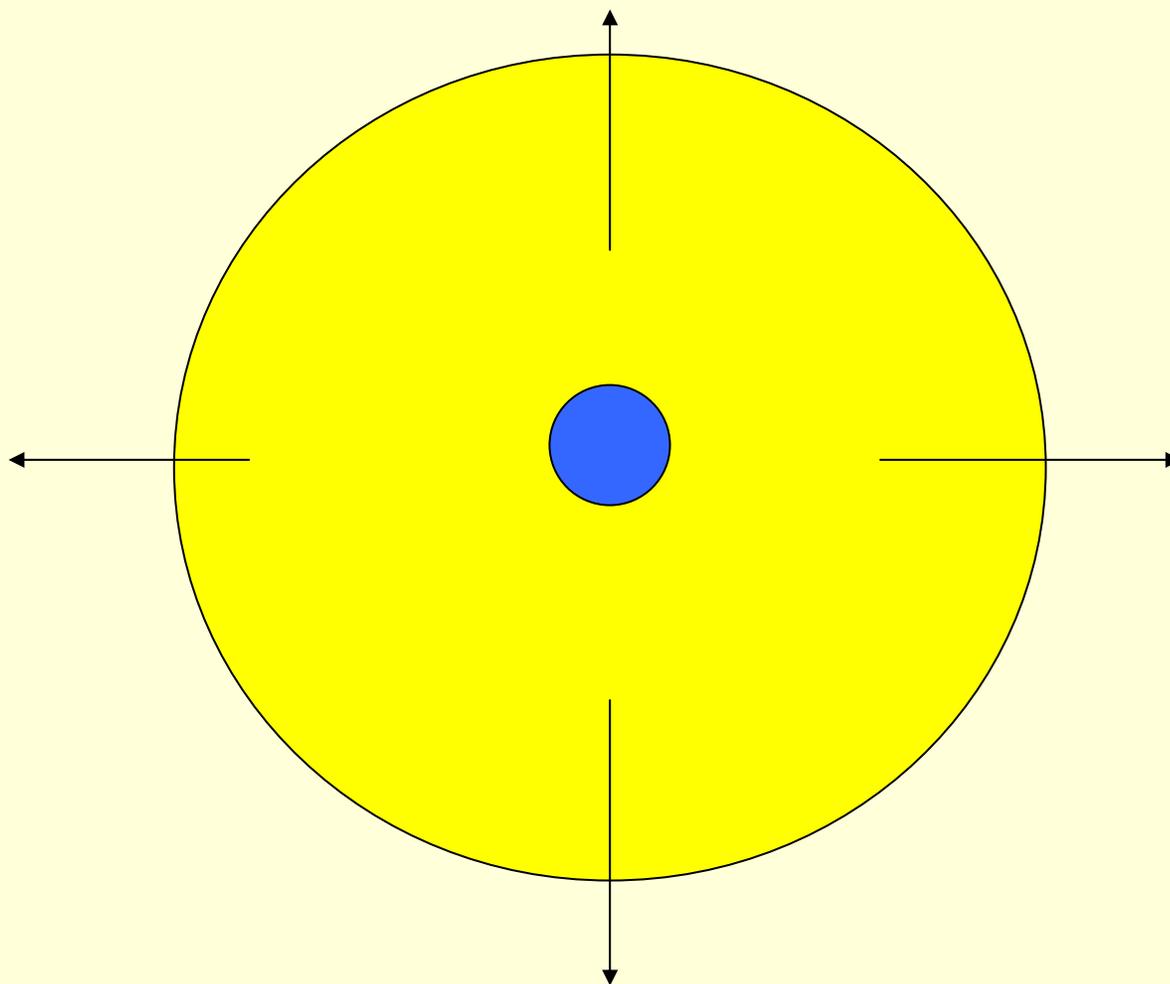
類太陽恆星

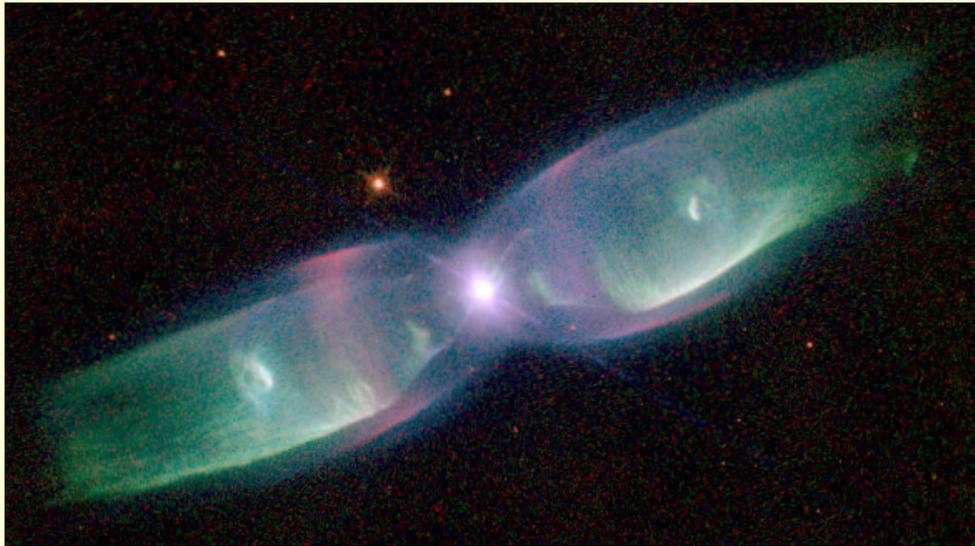
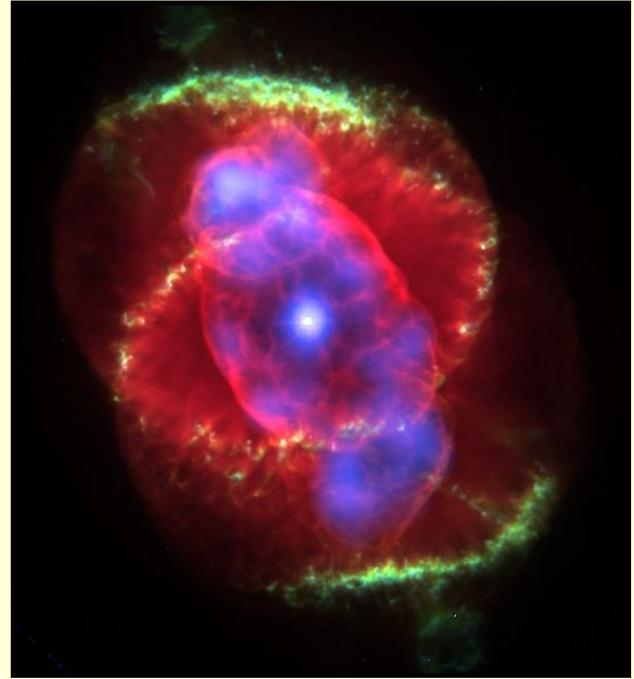
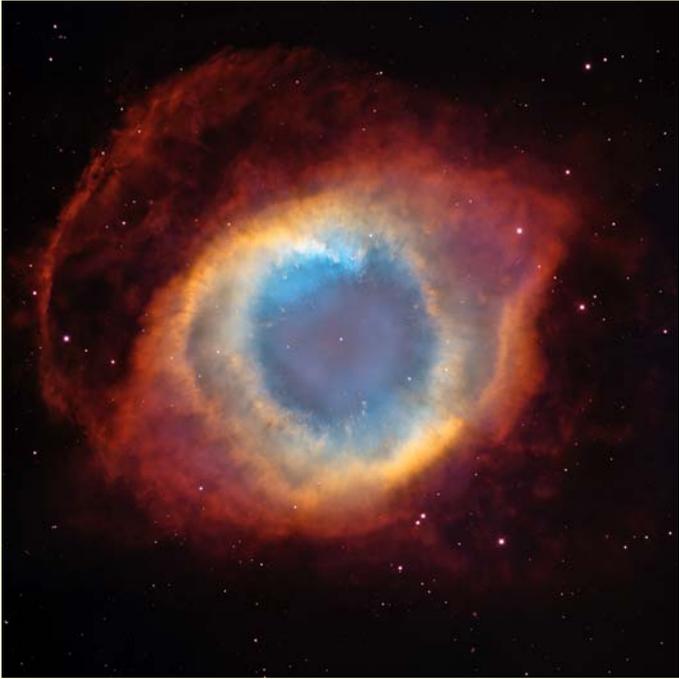
(~0.5 → 4 太陽質量)

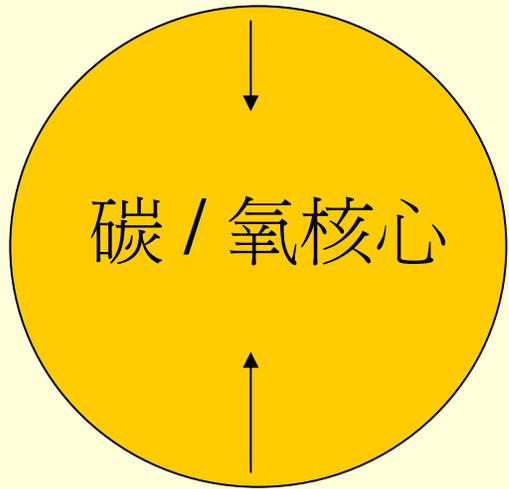


質量不夠大 → C/O ~~→~~ 更重的元素

外層 H/He 燃燒 \rightarrow 大量物質流失 \rightarrow 星雲

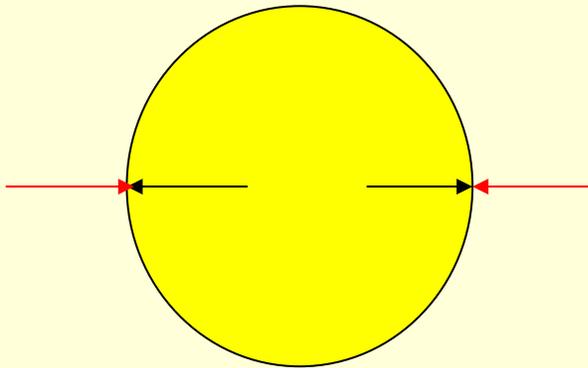




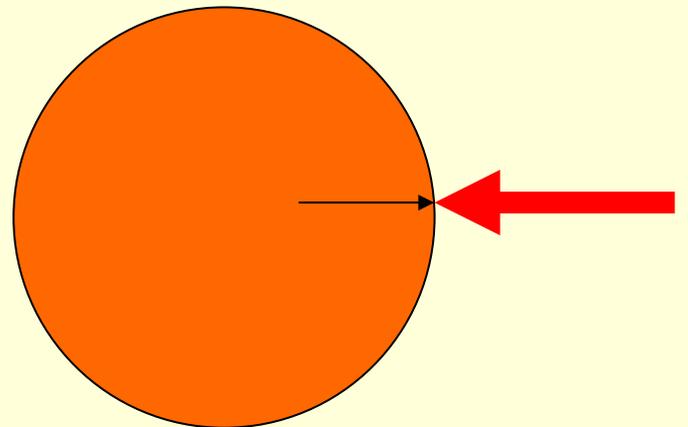


抗衡引力??

量子力學：密度足夠高 \rightarrow 電子簡併壓力



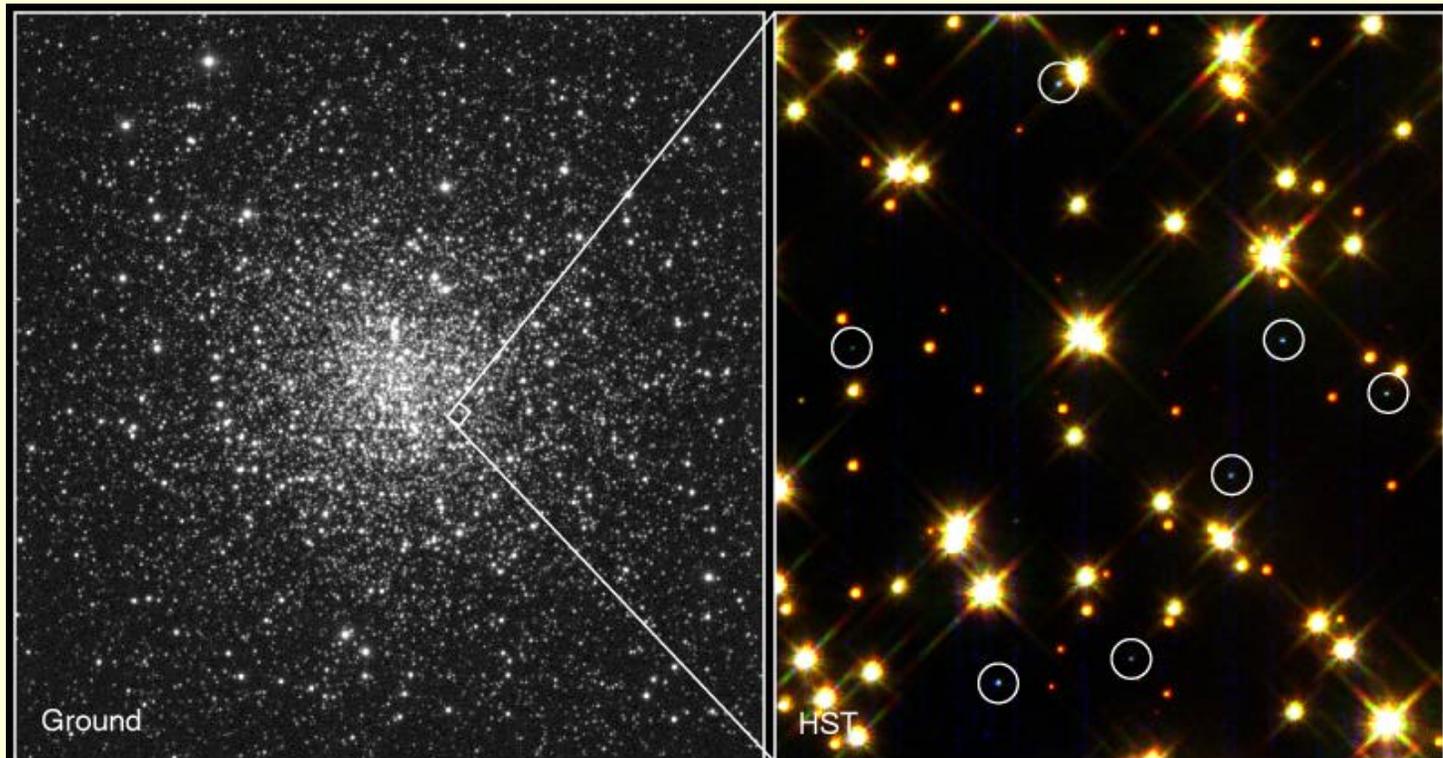
< 1.4 太陽質量



白矮星 (電子簡併壓力 = 引力)

質量: ~ 太陽

半徑: ~ 地球



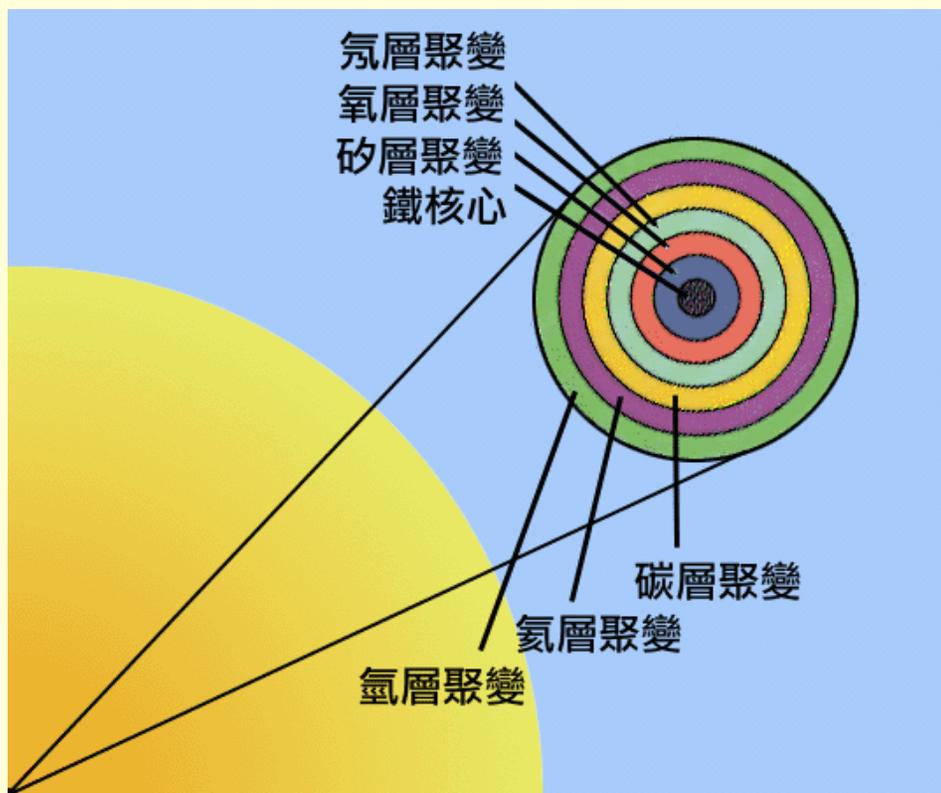
White Dwarf Stars in M4

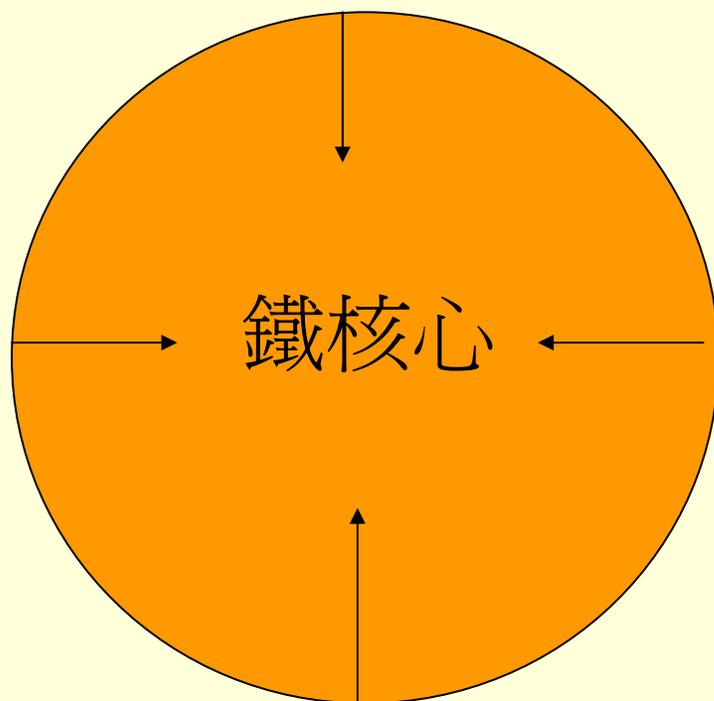
PRC95-32 · ST ScI OPO · August 28, 1995 · H. Bond (ST ScI), NASA

HST · WFPC2

質量 > 4太陽質量的恆星 → 核聚變製造更重的元素

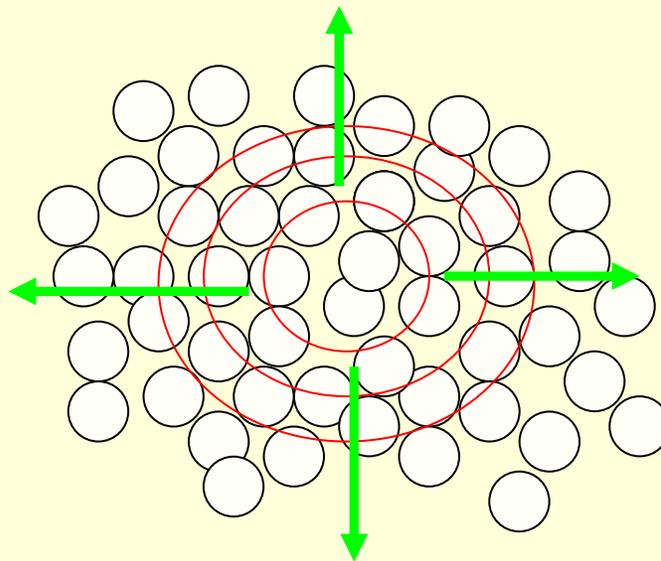
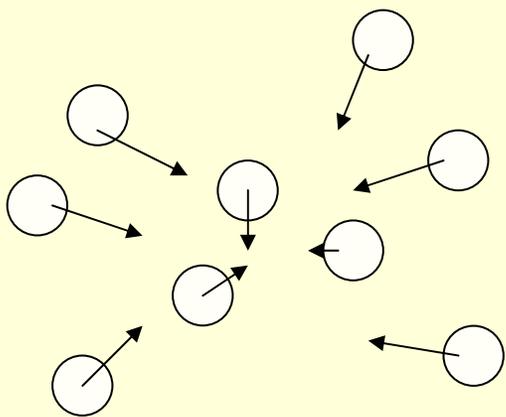
↓
鐵 (最穩定)





引力 → 塌縮

質子，中子



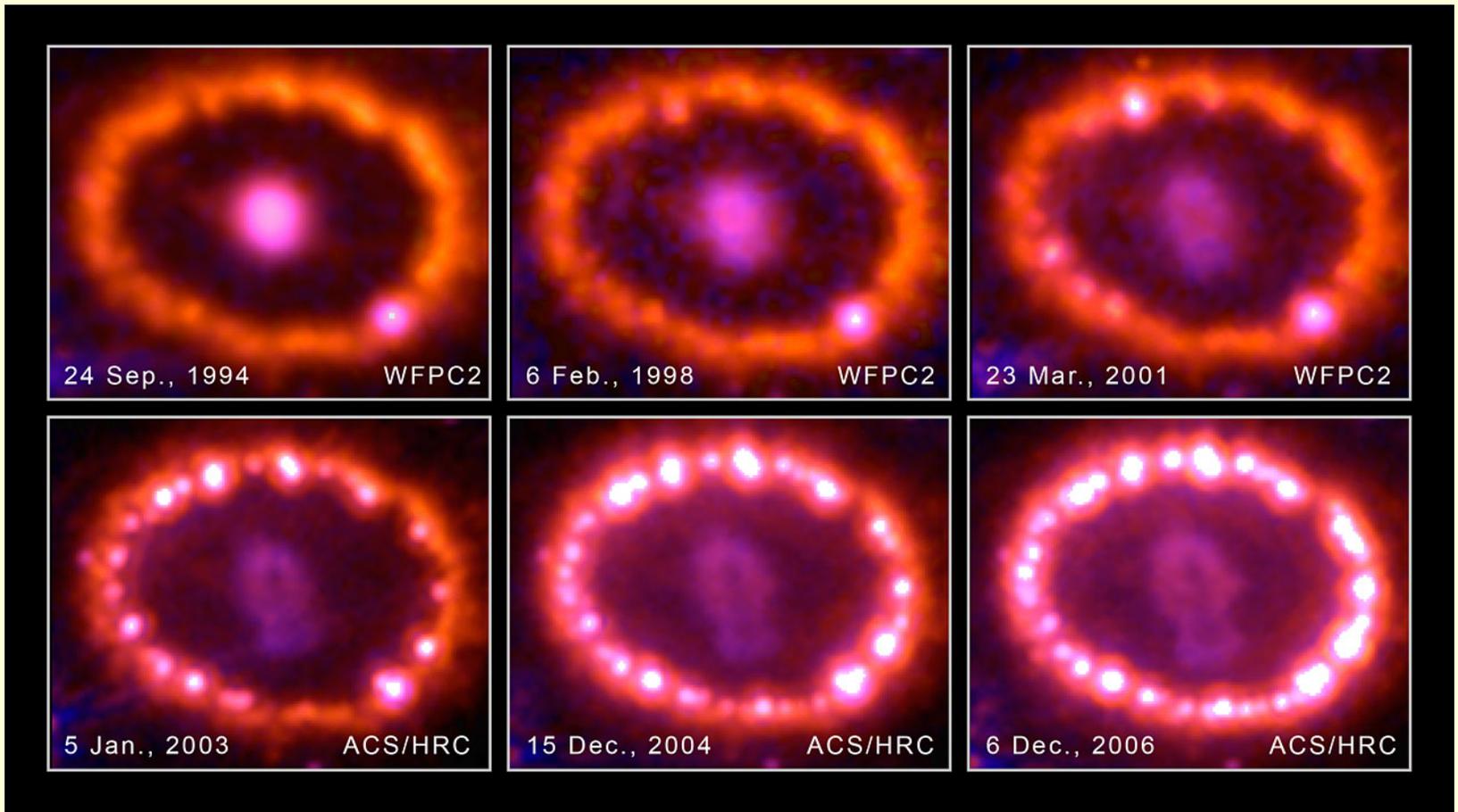
超新星



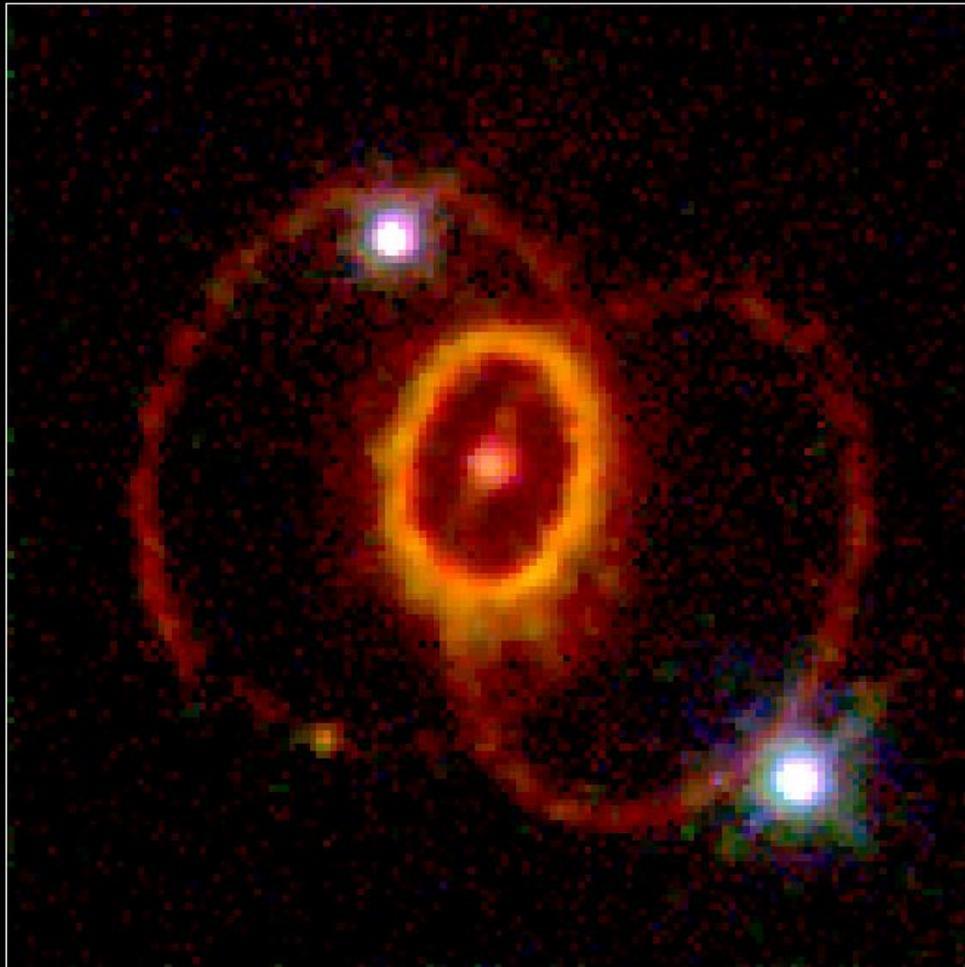
1987A

爆發後

爆發前



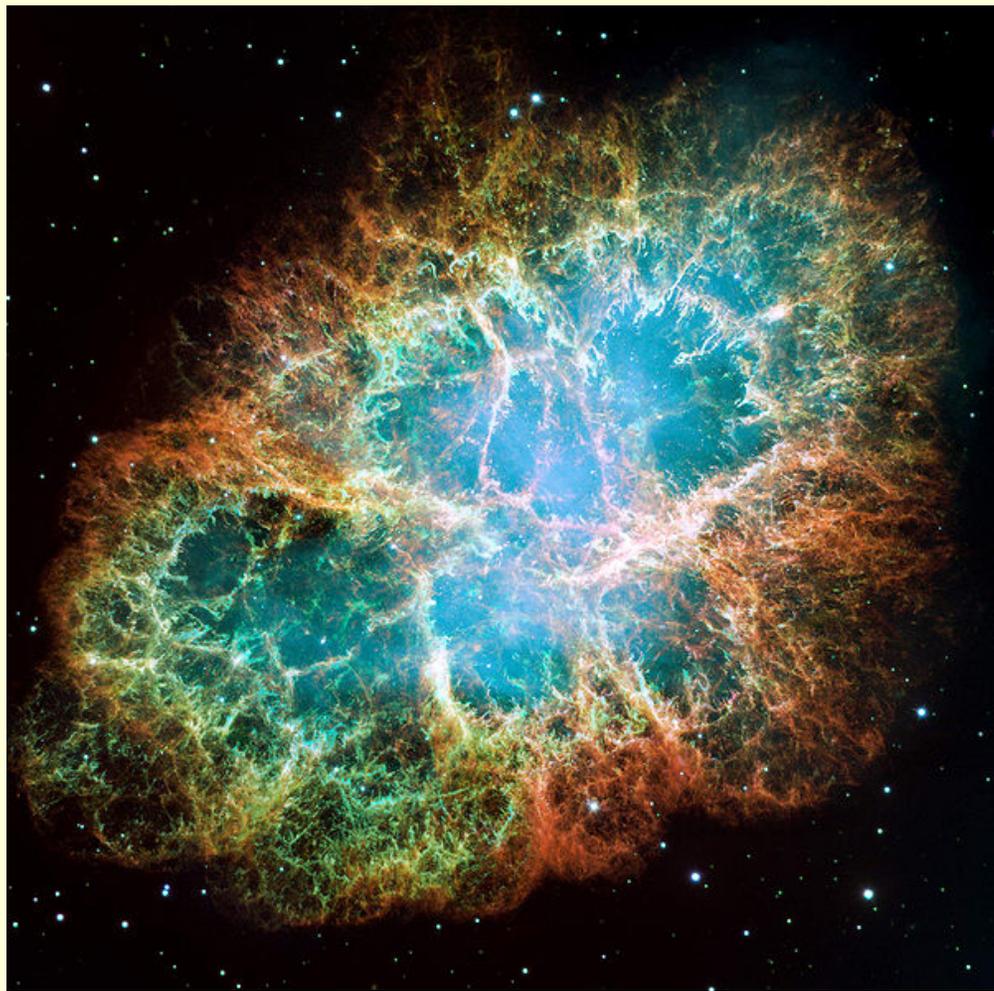
Supernova 1987A Rings



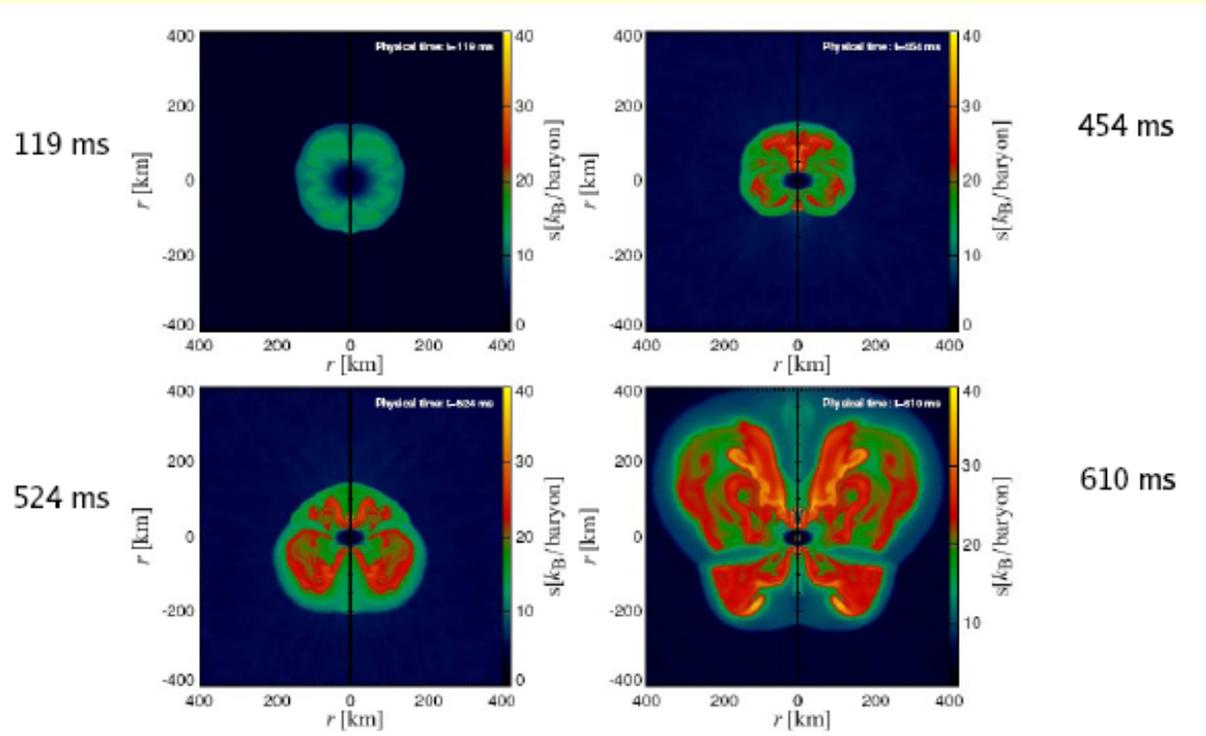
Hubble Space Telescope
Wide Field Planetary Camera 2



蟹狀星雲：1054年的一次超新星爆發後的殘餘物



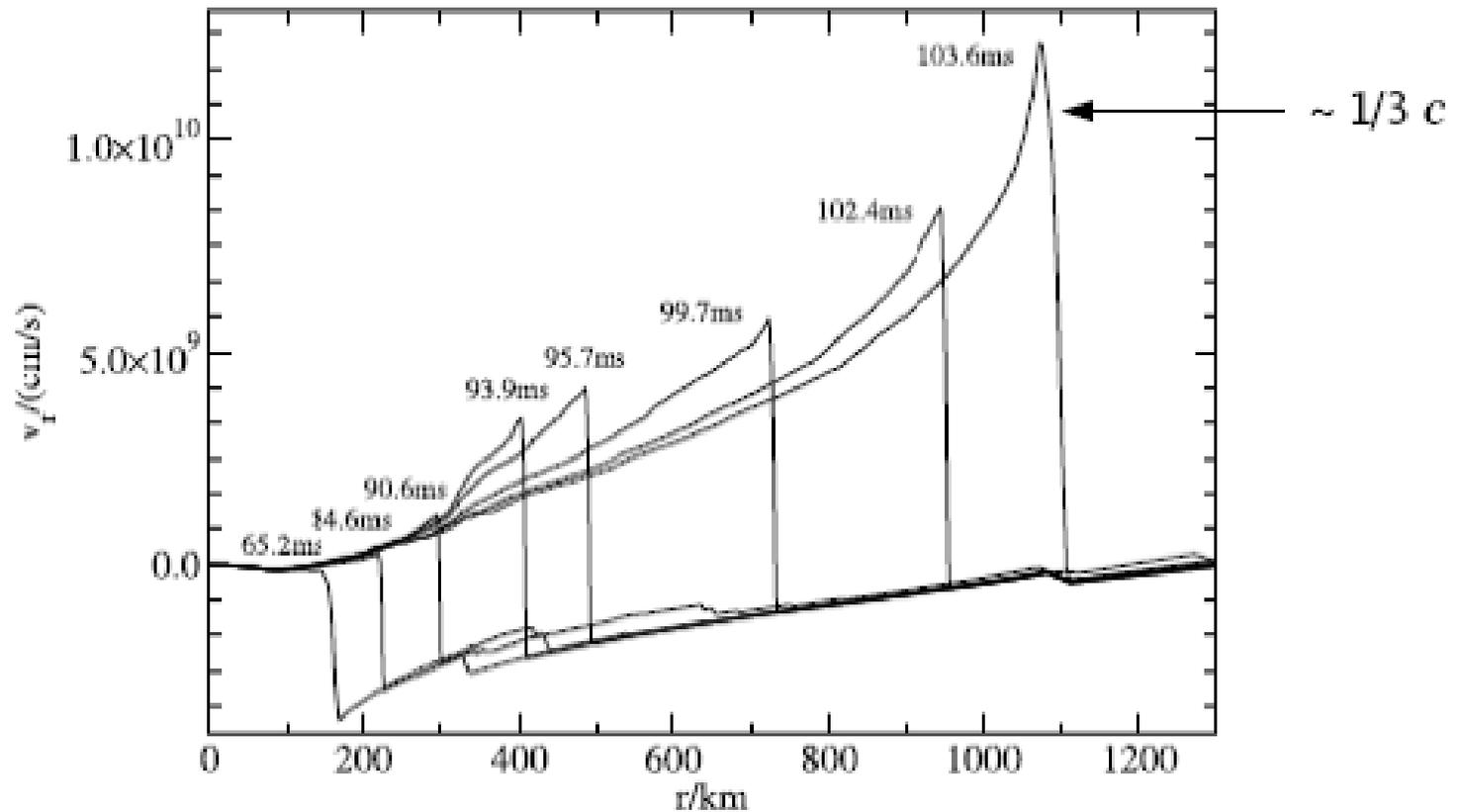
一顆質量=15太陽的恆星超新星爆發 (電腦模擬)



(Janka et al)

(NCSA)

激振波

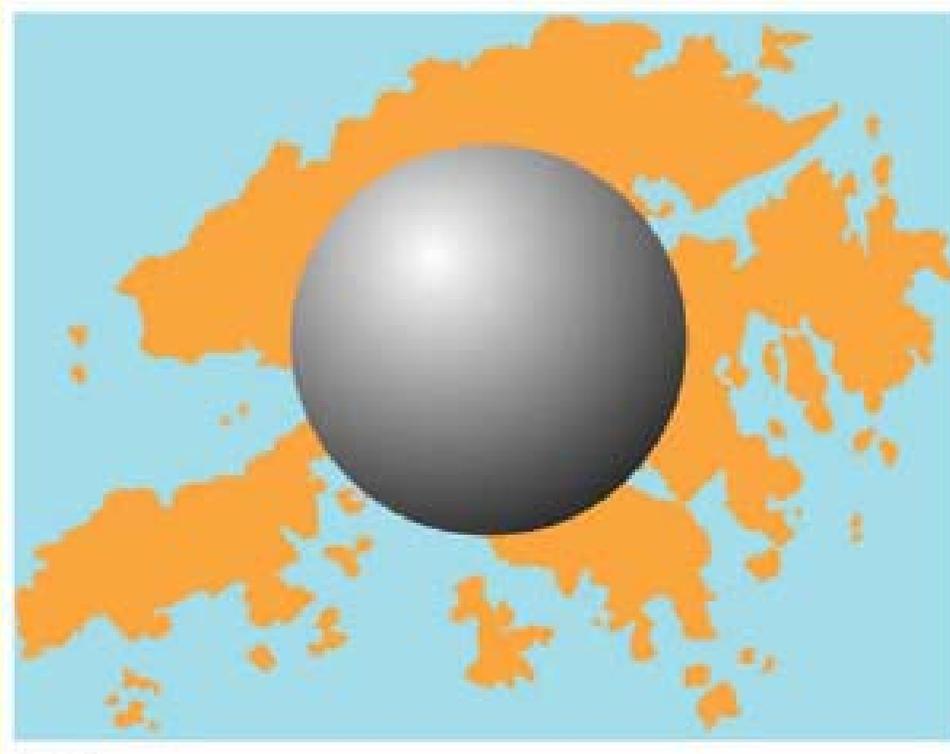


(Janka et al)

中子星 (中子簡併壓力 = 引力)

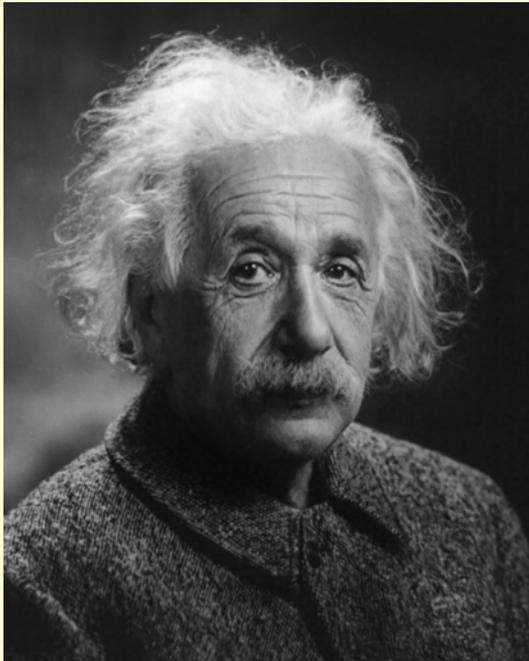
質量 ~ 1 - 2 太陽質量

半徑 ~ 10-20 km



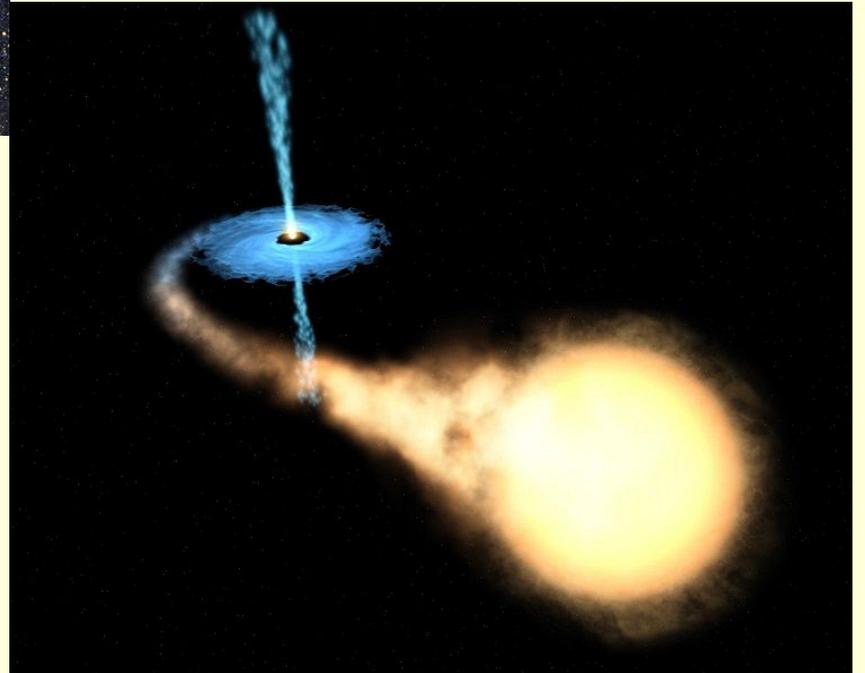
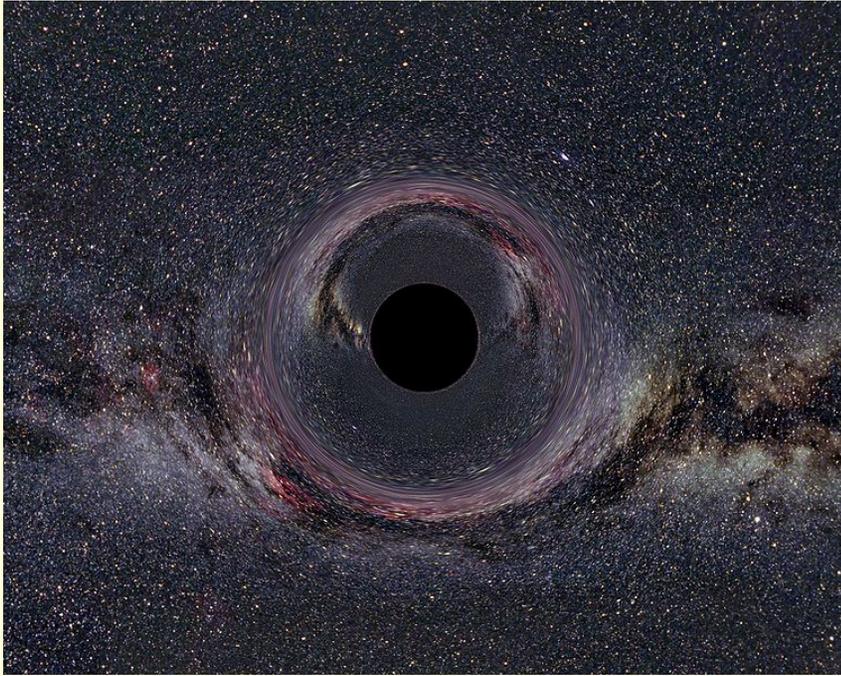
質量 $> \sim 20$ 太陽質量的恆星

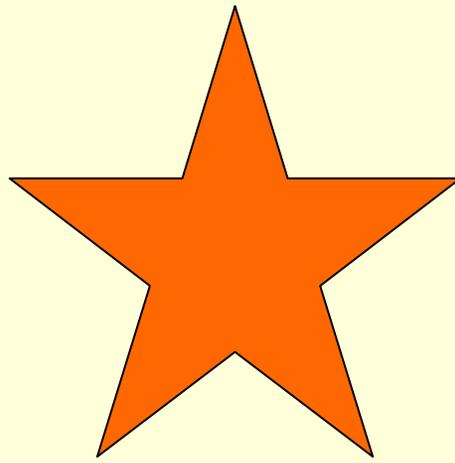
引力 \rightarrow 塌縮 \rightarrow 塌縮 \rightarrow 塌縮



廣義相對論：



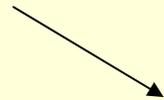




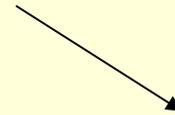
誕生



演化



死亡



新的星誕生!!

你的宇宙 由你發現



2009

國際天文年