

$$P = 13 \text{ days}$$

$$a = 7 \text{ million miles}$$

$$D = 20 \text{ light years}$$

$$M = 10.5$$

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$$13 \text{ days} = 3 \times 10^{-2} \text{ yr}$$

$$7 \times 10^6 \text{ miles} = 10^7 \text{ km} = 10^{10} \text{ m} \\ = 7 \times 10^{-2} \text{ AU}$$

$$a^3 = P^2 M \quad \checkmark \rightarrow \text{solve mass}$$

$$\frac{(7 \times 10^{-2})^3}{(3 \times 10^{-2})^2}$$

$$= \frac{350 \times 10^{-6}}{10 \times 10^{-4}}$$

$$= 35 \times 10^{-2} = .35 = \frac{1}{3}$$

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$$D = 20 \text{ l.yrs} \\ \approx 6 \text{ parsecs}$$

$$m - M = 5 \log (D/10 \text{ pc}) \\ = 5 \log (2 \times 3 \times 10^{-1}) \\ = 5 \left[ \log(2) + \log(3) + \log(10^{-1}) \right]$$

$$= 5 [0.3 + 0.5 - 1] \\ = 5 \times -0.2 = -1$$

$$10.5 - M = -1$$

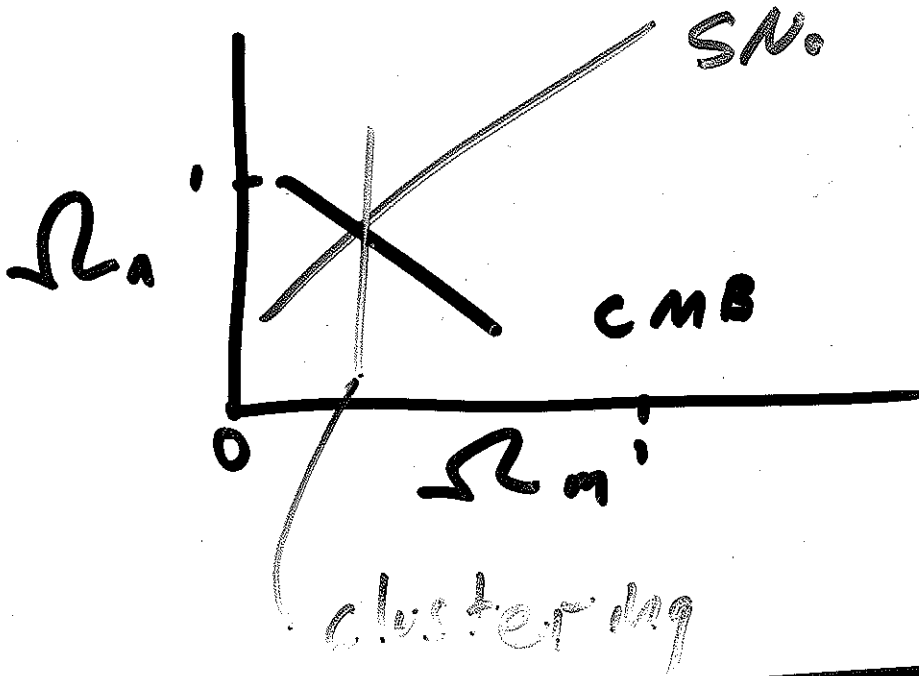
$$M = 11.5$$

$$10^{-0.4(M_* - M_0)} = b_*/b_0$$

$$10^{-0.4(11.5 - 5)} = 10^{-2.6} = 10^{-2.6}$$

$$\frac{b_2}{b_0} = 10^{-4} \times 10^{-3} = 2.5 \times 10^{-5}$$

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"epicycles"

ANOTHER FACT

we exist

life: complexity

: time to evolve

$$\Omega_n > 10^2$$

push Universes  
apart - no  
structure

$$\Omega_n < 10^{-2}$$

also - no structure

$$R_s = \frac{2GM}{c^2}$$

if  $G$  bigger

if  $c$  smaller

$R_s$  would be bigger

if  $R_s > R_{\text{white dwarf}}$

ALL stars end as black holes

No Carbon (or anything  
other than  $H, He$ )

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properties of carbon

would disappear

if fine structure constant

was slightly different

DRASTIC FINE TUNING  
of natural constants  
pre-requisite for life

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ANTHROPIC PRINCIPLE  
The fact that life exists is  
important for understanding  
basic physics/cosmology

Why do  $G, c, \Lambda, \dots$   
have the values they do

- 1) accident
- 2) life "created" on purpose
  - religious
  - "Strong Anthropic Principle"

Universe MUST have life

3) ~~MULTIVERSE~~  
MULTIVERSE

many universes with  
different sets of natural  
laws

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Generate many universes

- 1) beyond "cosmic horizon"
- 2) other dimensions  
(string theory)
- 3) evolutionary argument  
new universes form  
from old ones  
(black holes)

⇒ favor Universes that  
produce lots of black  
holes