ASTR 205: Stellar Astronomy
Class Assignment 6: Mar 22 2018

1. Scuba divers in clear tropical waters can see objects as far as 50 meters away. What is the opacity κ of the water? Compare your number with the average

   opacity in the Sun, which is 8 m^2 kg^{-1}. In which environment could you see further?

2. We can get some insight into the chemical evolution of the Sun over its lifetime by calculating its mean molecular weight at different times. Do this for

a) pure hydrogen
b) solar chemical composition X=0.70, Y=0.28, Z=0.02.
c) primeval chemical composition X=0.76, Y=0.24, Z=0
d) the core of the Sun today, which has been converting H → He for 4.6 Gyrs so that it is now about 60% He.

3. Oxygen burning in stars is very complex and has many channels. Here are just a few of them. Complete the following reaction sequences.

a) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{?}S_{?} + \gamma$

b) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{?}S_{?} + n$

c) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{?}P_{?} + {}^{1}H_{1}$

d) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{?}Si_{?} + {}^{4}He_{2}$

e) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{?}Mg_{?} + 2\ {}^{4}He_{2}$

4. Assume that the Sun has uniform density and derives its luminosity from a steady contraction. What decrease in the Sun's radius would be required over historical times (say last 5000 years) to account for the Sun's constant luminosity over that time. Express you answer also as a fractional change in radius. Is there any chance we could detect this change?

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1. $\lambda = 1/k\rho$

$$k = \frac{1}{\lambda \rho}$$

$\lambda = 50\,m$ ρ (seawater) $1029\,kg/m^3$

$$k = \frac{1\ m^2}{50\,m \times 1029\,kg}$$

$$= m^2/kg$$

$$1.9 \times 10^{-5}\ m^2/kg.$$

Scan $8\ m^2/kg$.

$$\lambda_{scan} = 1/k\rho = \frac{1}{8 \times 1400}\ \frac{m^2}{kg}$$

$$\lambda_{scan} = 8.9 \times 10^{-5}\ m$$

$= .01$ mm. (low because used average ρ.)

in any case are much smaller than ocean.

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Eq. $\frac{1}{\mu} = (2X + \frac{3}{4}Y + \frac{1}{2}Z)$

$\frac{1}{\mu}$ = # particles / unit mass

$\therefore \mu$ = mass/particle = molecular wt.

(a) $X=1, Y=0, Z=0 \Rightarrow$

$1/\mu = 2 \Rightarrow \mu = 1/2$ (proton mass)

(b) $X=0.7, Y=0.28, Z=.02.$

$1/\mu = (2\times0.7 + \frac{3}{4}\times0.28 + \frac{1}{2}\times0.02)$

$= 1.62 \Rightarrow \mu = 0.62.$

(c) $X=0.76, Y=0.24, Z=0.$

$1/\mu = (2\times0.76 + \frac{3}{4}\times0.24) =$

$1.52 + 0.18 = 1.70.$

$\mu = 0.59$

(d) $X=0.38 \quad Y=0.60 \quad Z=.02.$

(from $Y=0.60$, take $Z=.02$)

$\therefore 1/\mu = (2\times0.38 + \frac{3}{4}\times0.6 + \frac{1}{2}\times.02)$

$= 1.22$

$\Rightarrow \mu = 0.82$

(Compare c → b → d. see chemical evolution of Sun

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3. (a) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{32}S_{16} + \gamma$

(b) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{31}S_{16} + n$

(c) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{31}P_{15} + {}^{1}H_1$

(d) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{28}Si_{14} + {}^{4}He_2$

(e) $^{16}O_8 + {}^{16}O_8 \rightarrow {}^{24}Mg_{12} + 2\,{}^{4}He_2$

Oxygen burning has many channels. These are just a few of them.

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24. Energy output Sun = 4×10^{26} W ($J s^{-1}$).

5000 years = $5000 \times \pi \times 10^7$ s

$= 1.5 \times 10^{11}$ sec.

So total energy emitted = 6×10^{37} J.

Get energy from contraction

$PE_{sphere} = \frac{3GM^2}{5R}$.

$dPE = d\left(\frac{3GM^2}{5} R^{-1}\right)$

$dPE = -\frac{3GM^2}{5R^2} dR$.

$6 \times 10^{37} J = -\frac{3 \times 6.67 \times 10^{-11} \times (2 \times 10^{30})^2}{5 \times (7 \times 10^8)^2} dR$

$\therefore dR = -183{,}658$ m.

$dR = -183$ Km.

fractional change = .00026

probably too small to measure.

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