Astronomy 208 v. Y2K "Lecture 1" 9/19/00

Handouts
- class list form
- syllabus
- survey
- Barnard article

Introductions

Thurs 11:30 slow? Tues → Fri?

Viewgraphs "Physics of ISM"

www Web URL: cfa-www.harvard.edu/~agoodman/astro208

What's the Course About?

→ Physics of the ISM v.g. ←

What's out there? Where is it? What's it Doing? How do we find out?

FORMAT: Relies heavily on STUDENT preparation

~ • Tuesdays "lectures"
~ • Thursdays 50/50 lecture/discussion

[THIS Thursday Barnard Article – Need Volunteer "discussant" xtra points for volunteering for the 1st one!]

Future articles & schedule, including discussants will be on-line through web site:
Discussant provides html summary w/ links by 12 hrs in advance

AY208 9/19/00

More Logistical Notes

→ Auditors may attend journal discussions if they read articles.

www → Review p. 1 of Syllabus

"Texts"

really none – best refs on-line

www through web site — sug source amazon.com (& Wolbach)

www really required readings are articles on-line through web site

Problem Sets

- every 1.5 - 2 weeks
- working together OK but please don't "copy"
- Some computer work / simulation
- will rely on Journal articles for some problems

Exams: Final (take-home) req. of CORE course

Grade: 40% final 35% psets 25% journal site/presentation

Office Hours: By appt AG

HJC ← prob set ?

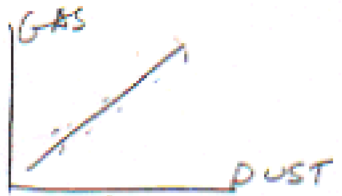
(1.1) "Earliest Observations"

How do we know there is an ISM? (Other than existence of AY 208)

In MW & other galaxies: { extinction & reddening } → dust (see Barnard article)

"stationary lines" from binary ☆'s
lines from ☆'s Doppler shift due to ☆'s motion
interstellar ("stationary") lines don't shift w/orbit

gas & dust correlated (see Fig 1.1 of Spitzer)



N_H column density ← from strength of absorption lines

E_{B-V} ← "color excess" ← from stellar continuum

Even the "Dense" ISM is a Low Density Environment

$T = 0° = 273 K$
$P = 1 atm$
1 mole = 22.4 ℓ for any low-density gas
$N_A = 6.02 \times 10^{23}$ (Avogadro's #) = # molecules/mole

6.02×10^{23} air molecules in 22.4 ℓ

$1 ℓ = 1000 mL = 1000 cm^{-3}$

~ Density in this room ~ 6×10^{20} ptcls/cc

1 Torr = 1. mm of mercury

1 atm = 760 torr

vacuum @ 10^{-8} torr is $\frac{10^{-8}}{760} = 1.3 \times 10^{-11}$ times less dense than air @ 0°C

$6 \times 10^{20} \times 1.3 \times 10^{-11} = 8 \times 10^{9} \approx 10^{10} \frac{ptcls}{cc}$

best vacuum on Earth

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(1.2) The Modern View

a, b, c Composition, Extent, Temp Structure

[Keep in Mind: Density of ★'s in the MW $\approx 0.125\ M_\odot/pc^3$]

(a) Composition of (Milky Way) ISM: (constituents)

see B&O p. 346

gas: 60% H, 30% He by mass

recall $m_{He} = 4 m_H$ so if $m_{TOT} = 90$

60 H $\frac{30 He}{4}$ } 8 x as much H by #

~80% H, 10% He by # 60 H 7.5 He

other ~10% trace elements in ~⊙ abundances (really <10%)

Gas density in GALAXY $\Rightarrow 0.025\ M_\odot/pc^3 = \frac{1.85\times10^{-24}\ g/cc}{1\ amu \approx 1.67\times10^{-24}} \approx n = 1\ ptcl/cc$

How is that density estimated?

M_{TOT} (MW) ~ $1.4\times10^{11}\ M_\odot$ (from rotn curve)

D ~ 40 kpc (estimate from HI & CO)

scale ht ~ 140 pc (from HI maps)

→ Volume $\approx 2\times10^{67}\ cm^3$

$\Rightarrow \rho_{with\ ★'s} \approx 1.4\times10^{-23}$ $\frac{M_{gas}}{M_{★'s}} \sim 0.2$ ← leftover must be gas!

$\Rightarrow \rho_{gas} \approx 2.8\times10^{-24}\ g/cc \Rightarrow n = 1$ or $2\ ptcl/cc$

Atomic? Molecular? Ionized?

At $n = 10$ to $50\ cm^{-3}$ → molecular needs dust as catalyst

(will discuss ionization & recombination, association & dissociation)

Back to Constituents

Dust (molecules too big to name up to rocks too small to name)

$$N(a) \propto a^{-3.5}$$

a = size
many very small particles
e.g. 0.2 μm

Density in the Galaxy ~ 0.002 $M_\odot/pc^3$
recall gas ~ 0.025 $M_\odot/pc^3$
so $\rho_{dust}/\rho_{gas} \approx 0.1$

Cosmic Rays (charged) (high-energy {protons, nuclei, antiprotons, e^-, e^+})

0.5 eV/cm³

mass equiv ≙ 9×10^{-34} g cm^{-3}

Note: 1 eV = 1.6×10^{-12} erg
$E = mc^2$ $m = E/c^2$
0.5 eV = 8×10^{-13} erg ⇒ $\frac{8 \times 10^{-13}}{(3 \times 10^{10})^2} = 8.9 \times 10^{-34}$ grams

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Magnetic Fields

~10^{-6} gauss ~1 μG ⇒ 0.2 eV/cm³   actually a bit more?
(~enough to confine cosmic rays)

Constituents Cont'd

Starlight 0.5 eV/cm^3

neglected contributors: rotational energy from differential rot'n of Galaxy + turbulent energy w/in clouds

1.2 b,c extent & temperature structure (see Web Pages)

+ Table 18.1 of B & D