(Astro)Physics 343 Lecture # 5:
The Interstellar Medium

Data for Lab # 2

Each of you should have 5 datasets in your email as of (very) early this morning.

Start times may be different from expectations ("0.0" glitch in some script fragments; Friday script had to be restarted midway through; etc.). The scripts as they were run are at http://www.physics.rutgers.edu/~ajbaker/ph343/lab2data/ .

Local conditions = ??? Drive motor stalled at one point on Friday: possible snow/ice/wind loading on dish?

Report for Lab # 2

Lab # 1 will be graded by the end of this week so that you can have feedback on content.

On call office hours this week:

Baker for Sections A, C, and E.

Fadely for Section B and D.

The interstellar medium and its variants

ISM = interstellar medium = whatever gas and dust exists in the space between a galaxy's stars.

ICM = intracluster medium = hot gas filling the volume between galaxies in a group or cluster

IGM = intergalactic medium = material that has been ejected from galaxies or never made it into a galaxy in the first place

Why should we care about the ISM?

Tongue in cheek answer: every astronomy talk can be followed by one of three (ISM-related) questions:

(1) What about dust?

(2) What about magnetic fields?

(3) What about the initial mass function (i.e., relative numbers of newborn stars of different masses that result when a large gas cloud turns into stars all at once)?

Why should we care about the ISM?

Serious answer: the ISM serves as the raw material for star formation and the dumping ground for the products of stellar nucleosynthesis (notably, all elements heavier than helium).

Moreover, the ISM affects nearly all observations we make by absorbing, scattering, or swamping the radiation from other sources of interest.

(for dust, absorption + scattering = extinction)

Key property of the ISM: composition

Gas mass fractions X (hydrogen) + Y (helium) + Z ("metals") = 1:

Shortly after the Big Bang: no stars yet

$X = 0.75$

$Y = 0.25$

$Z = 0.00$

In the Sun (and surrounding ISM):

$X = 0.739$

$Y = 0.248$

$Z = 0.012$ **(of which oxygen contributes 0.005)**

Key property of the ISM: phase

Two parcels of gas with the same composition can have very different physical states. We characterize the phase of interstellar gas with our answers to two questions:

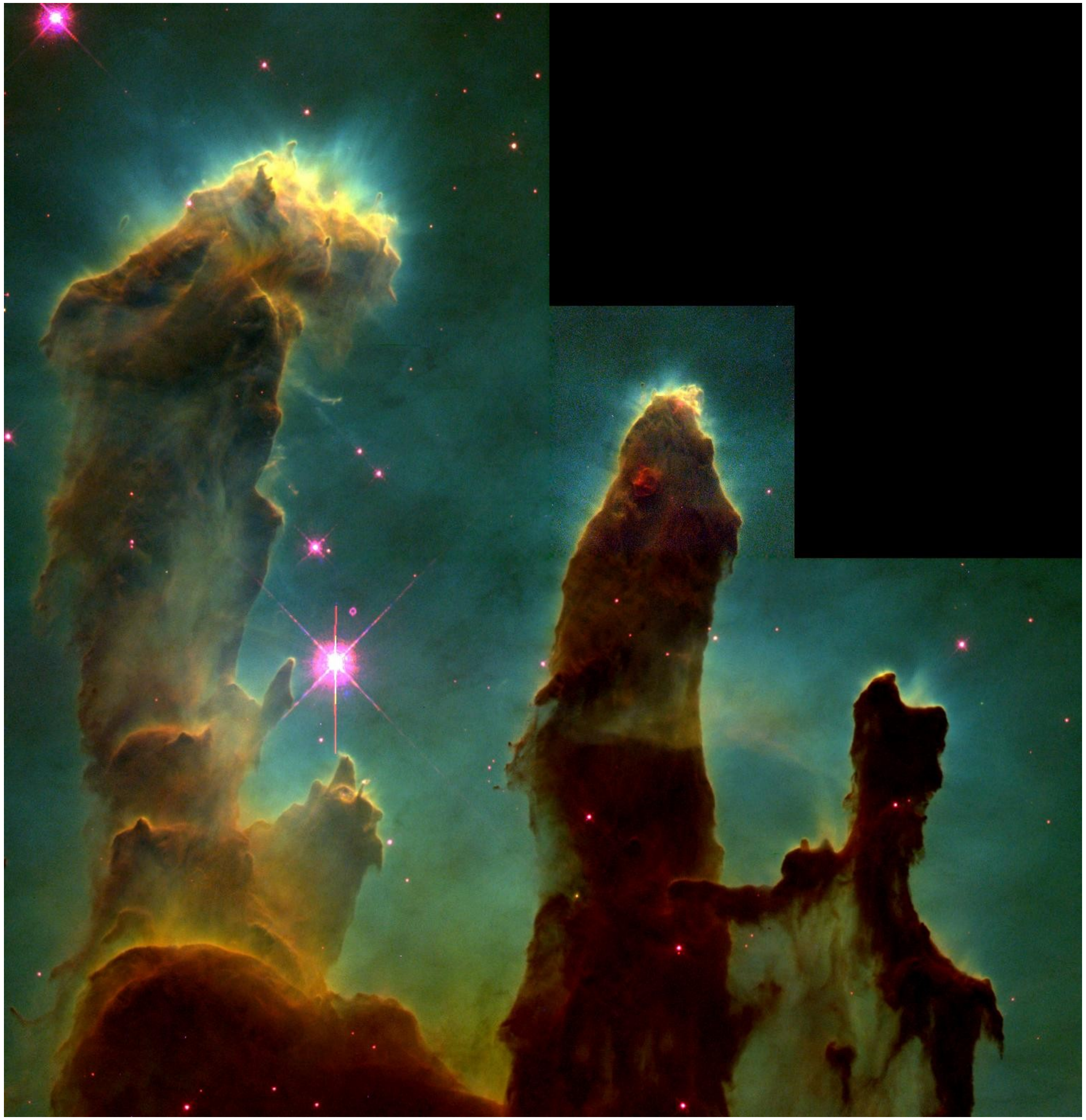
(1) In what form is the hydrogen predominantly found (ionized, neutral, and/or molecular)?

(2) What are the temperature and density of the gas?

Observed phases of the ISM

Phase	n (cm^{-3})	T (K)	nT (K cm^{-3})	% V	% M
hot ionized	0.003	10^6	3000	50	4
warm ionized	0.1	8000	800	25	14
warm neutral	0.5	8000	4000	30	38
cold neutral	50	80	4000	1	30
molecular clouds	> 2000	10	> 20000	0.5	13

Molecular gas: birthplace of stars

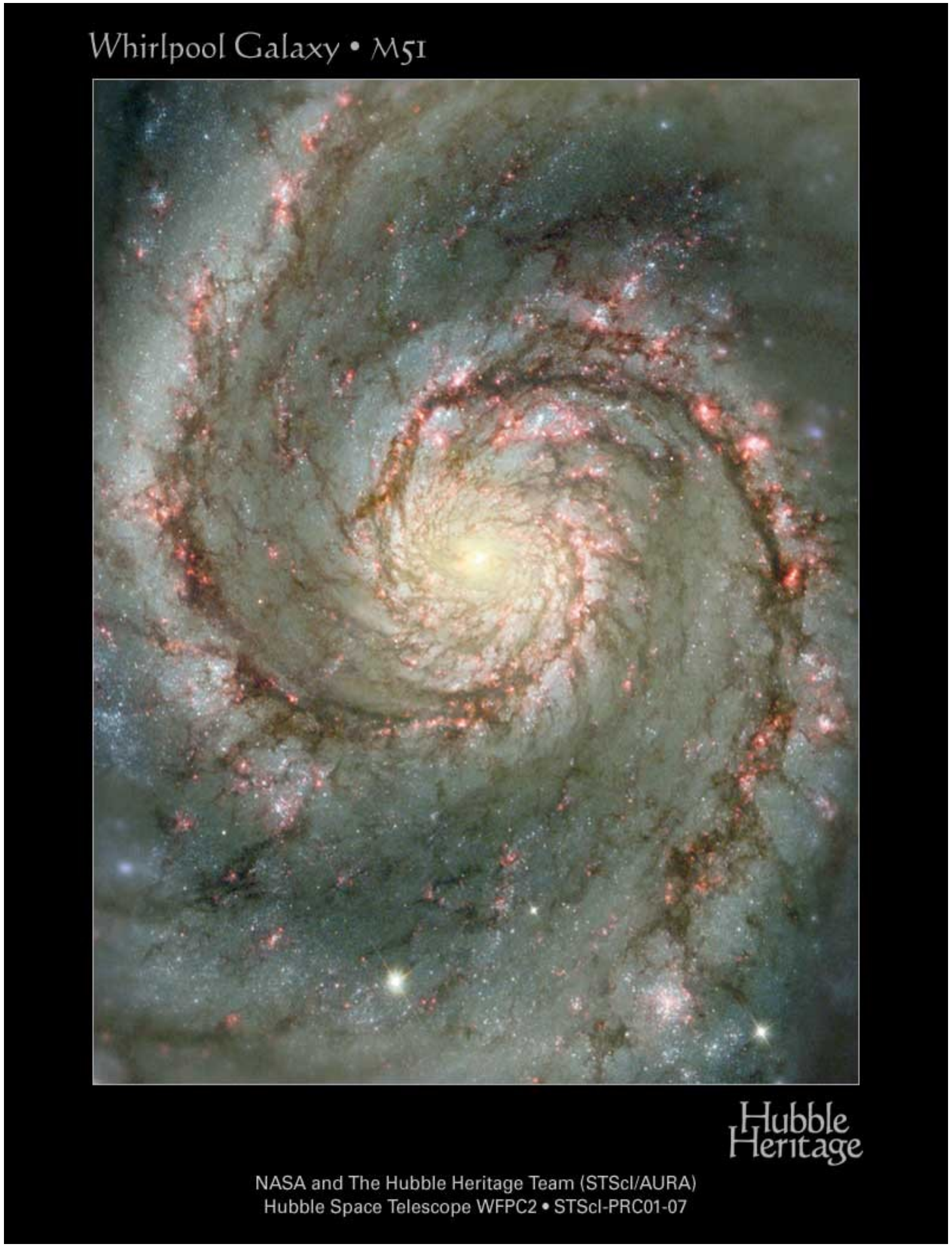


Eagle Nebula, imaged with *Hubble Space Telescope*:

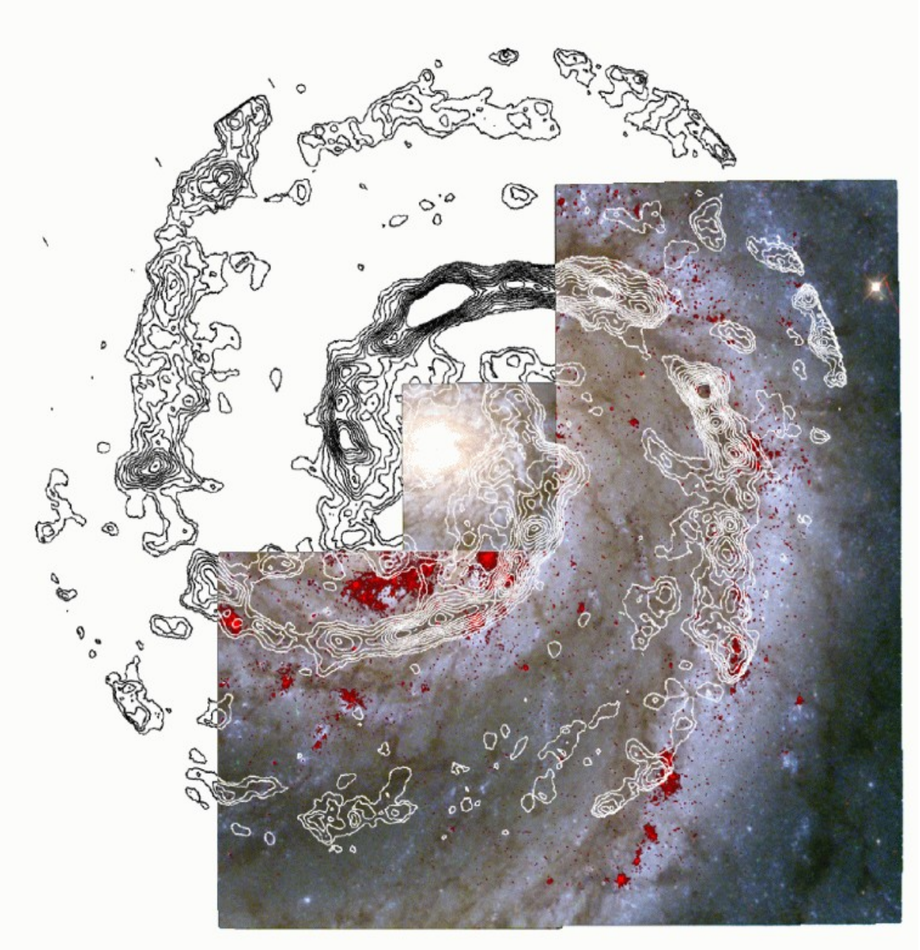
young stars that have emerged from their dusty birth clouds

+ still younger stars that are still enshrouded

Molecular gas: birthplace of stars

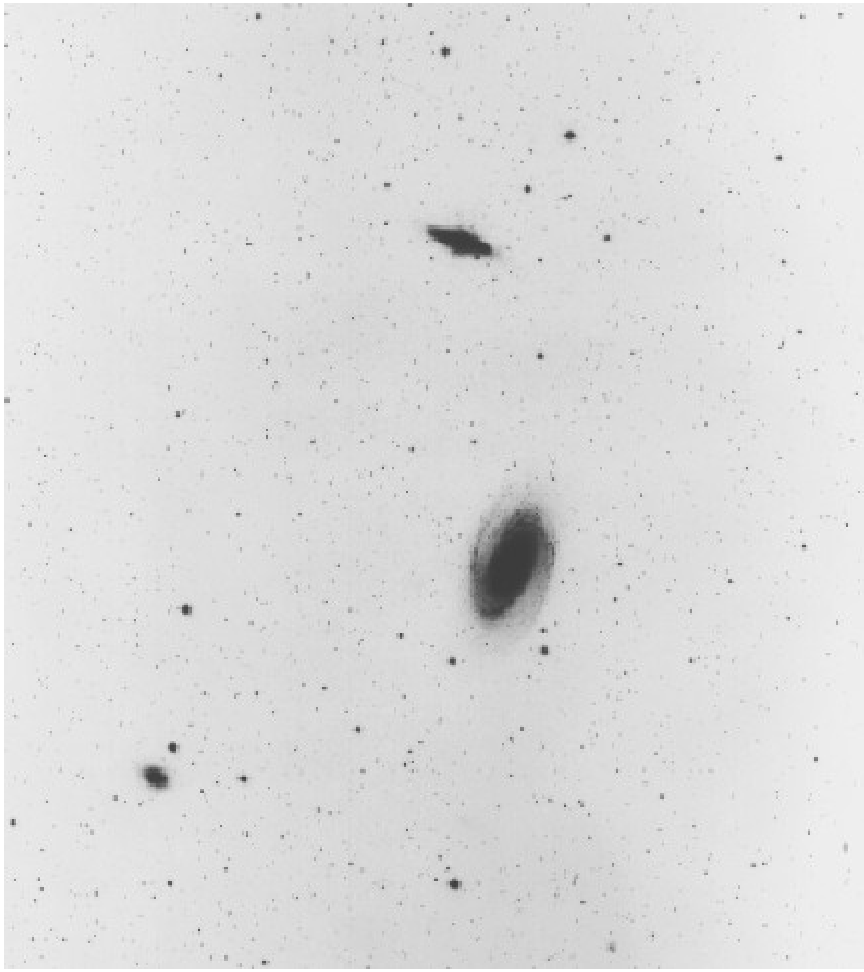


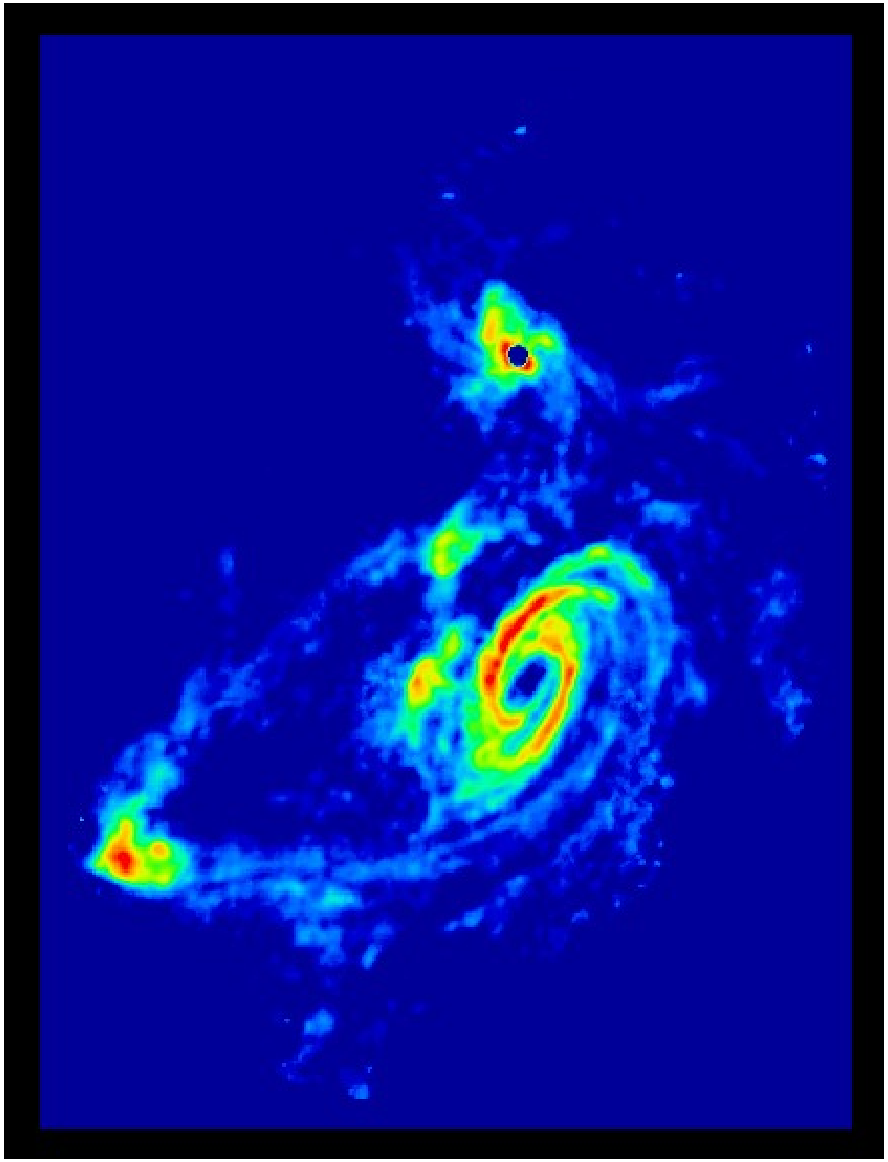
M51: CO contours overlaid on Pa α emission + optical light



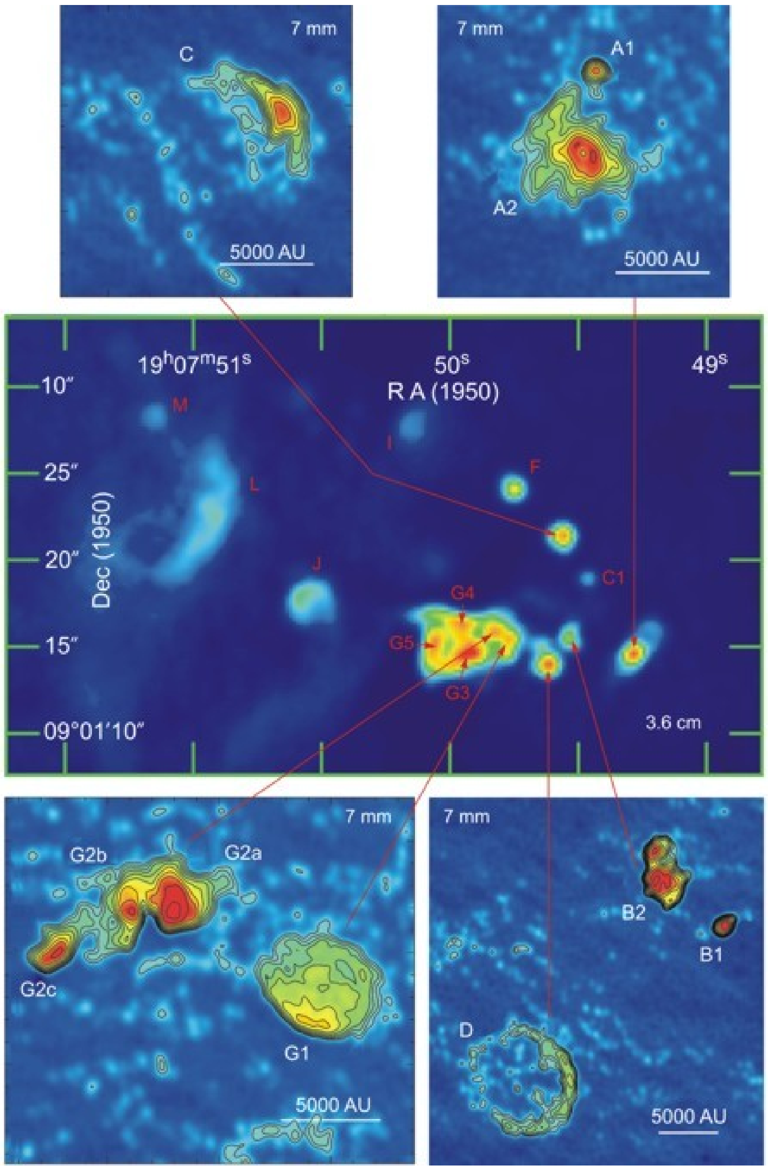
Atomic gas: a major gas reservoir

M81 group: optical starlight (left) + VLA HI (right)





Ionized gas: HII regions...

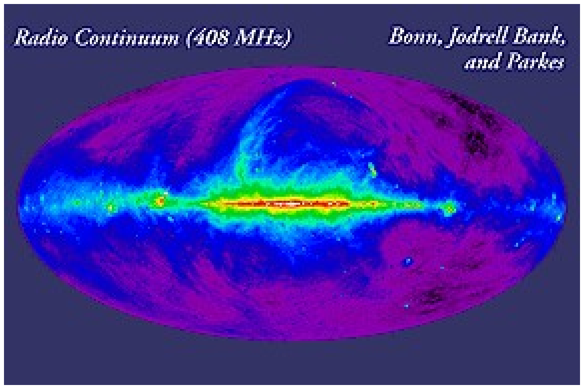


Free-free emission from young, "ultracompact" (high-n_e) HII regions in Milky Way: middle = 3.6cm, insets = 7mm

C. DePree, M. Goss, J. Welch, & D. Wilner

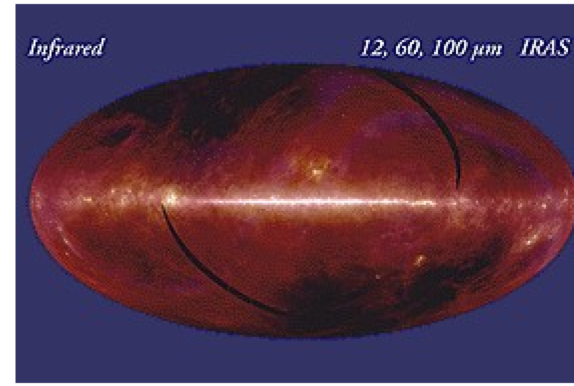
...and superwinds

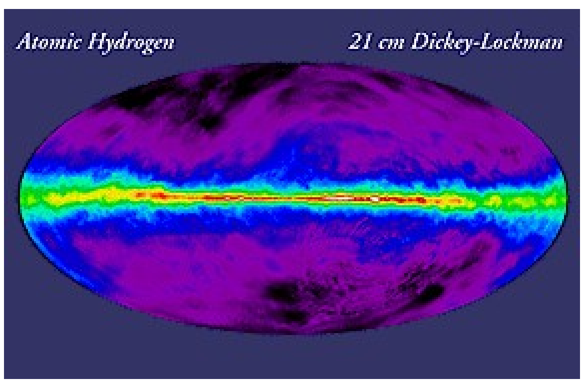
A multiwavelength view of the Milky Way



radio continuum

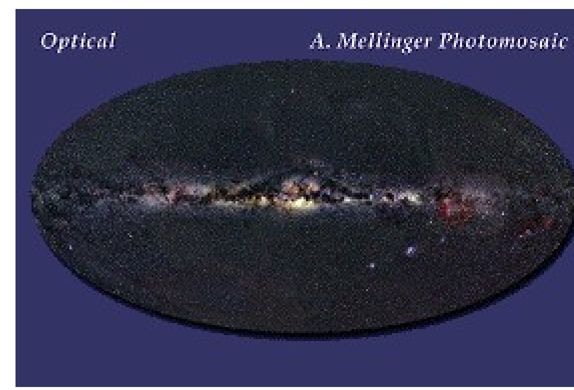
infrared (dust)

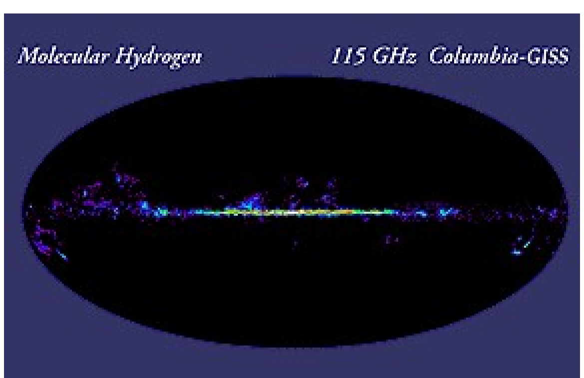




HI

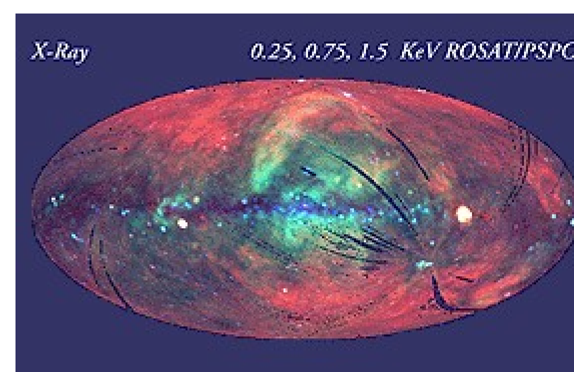
optical





CO (H_2)

X-ray



Pressure equilibrium

Phase	nT (K cm^{-3})
hot ionized	3000
warm ionized	800
warm neutral	4000
cold neutral	4000
molecular clouds	> 20000

Several phases of the ISM have the same thermal pressure as each other (nkT). This makes sense: a hot, dense bubble of gas will tend to expand until it reaches pressure equilibrium with its surroundings.

Molecular clouds do not follow this pattern: they are bound by self-gravity!

Quiz