Escola Avançado de Astrofísica

13/09/2004

Itatiba, São Paulo, SP.

Radio Observação do meio interestelar local

José Williams S. Vilas-Boas

- 1.1 - Pré-Socrático:

- Anaximandro e Anaximenes (476 a.c.)

" The Earth and all celestial bodies were born from a rotating condensation of gas."

- 1.2 – Chinese:

- Chi Meng (25 a 250 d.c.)

"The sky was empty without any matter... Not having frontiers. The Sun, the Moon, and the stars were floating in space. "

- 1.3 – Renascence

- La Place (1749-1827)

"The Solar System was born from a primordial rotating cloud of gas (nebular hypothesis)"

The Interstellar Medium

First observational evidence of the interestellar medium

Williams Hershel (1780)

Observed dark areas in the sky surrounded by a large concentration of stars.

´´we are observing through holes in the galaxy´´

First scientific discussions about the existence of this medium

John Hartman (1904)

Stationary lines toward a binary system: they are not produce in the star but somewhere between us and the binary.

The Interstellar Medium

18 years later, the idea that the emission could originate from a region close to the binary was accepted.

Otto Struve comments about this discussion:

"The hypothesis of an interstellar substratum embodying the whole Galactic system is the most satisfactory at present. This hypothetical substratum shares the rotational motion of the stars around a distant central mass in galactic longitude 325°"

Trumpler (1930)

Observed the reddening of the stars – No special attention was given to this result.

Charles Townes (1950)

Important discussion about the existence of NH_3 molecule in the interstellar medium.

In the 60 the concept of interstellar medium was well accepted. However, only after the detection of H_2O (6_{16}-5_{23}) and NH_3(J=K=1), in the Galactic center, the idea that this gas could have complex molecules was out of question.

In 1968 a very intense and narrow line was detected in the interstellar medium, named Nebulium.

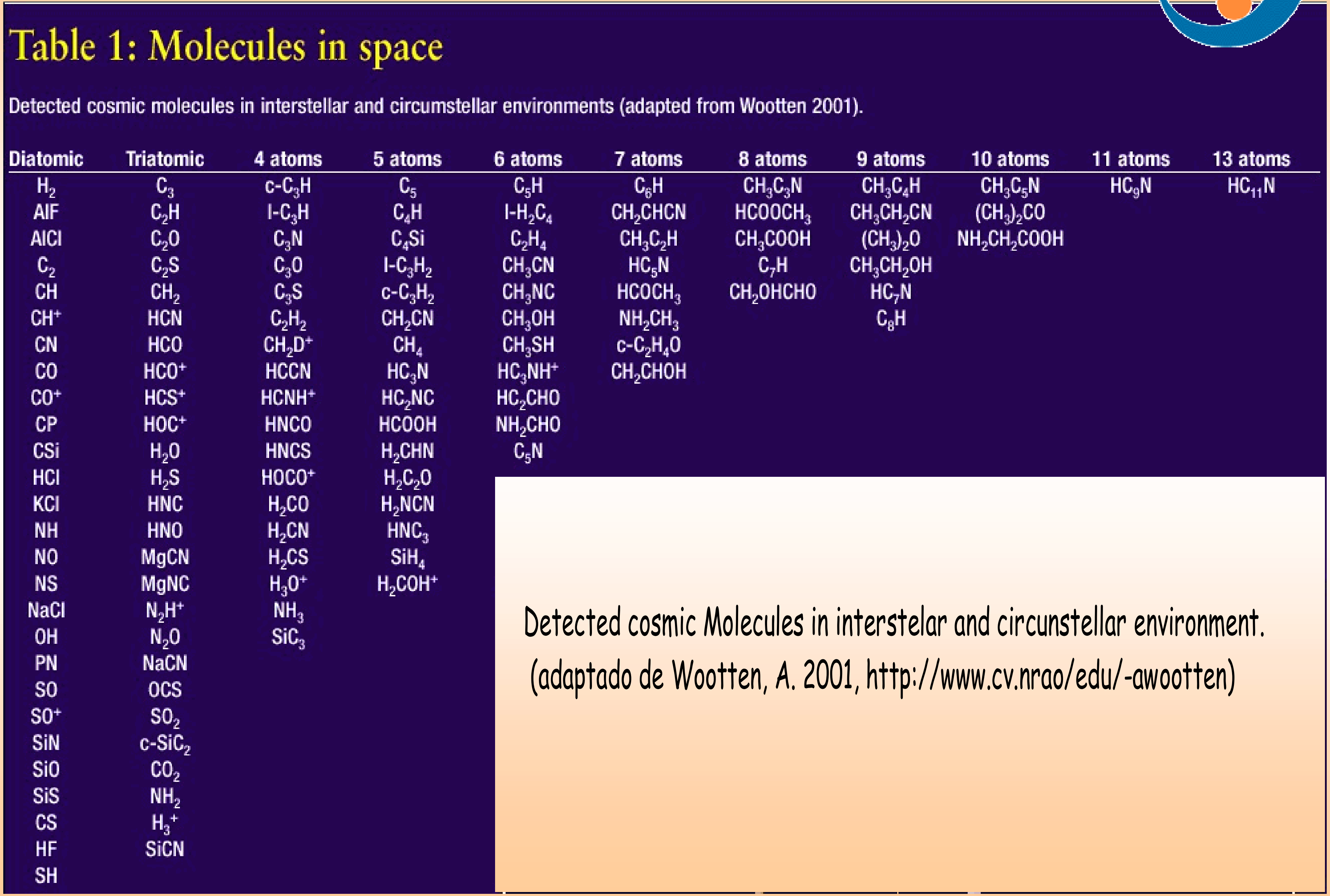


Table 1: Molecules in space

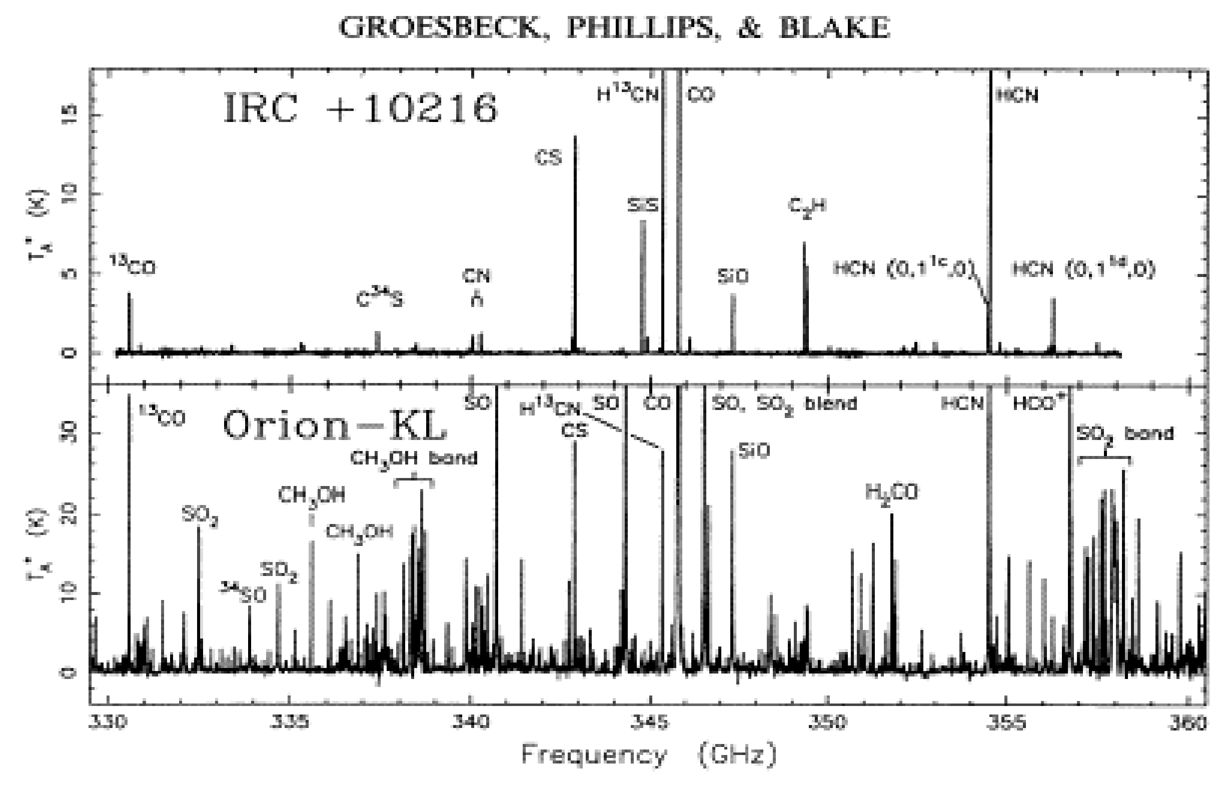
Detected cosmic molecules in interstellar and circumstellar environments (adapted from Wootten 2001).

Diatomic	Triatomic	4 atoms	5 atoms	6 atoms	7 atoms	8 atoms	9 atoms	10 atoms	11 atoms	13 atoms
H_2	C_3	c-C_3H	C_5	C_5H	C_6H	CH_3C_3N	CH_3C_4H	CH_3C_5N	HC_9N	$HC_{11}N$
AlF	C_2H	l-C_3H	C_4H	l-H_2C_4	CH_2CHCN	$HCOOCH_3$	CH_3CH_2CN	$(CH_3)_2CO$		
AlCl	C_2O	C_3N	C_4Si	C_2H_4	CH_3C_2H	CH_3COOH	$(CH_3)_2O$	NH_2CH_2COOH		
C_2	C_2S	C_3O	l-C_3H_2	CH_3CN	HC_5N	C_7H	CH_3CH_2OH			
CH	CH_2	C_3S	c-C_3H_2	CH_3NC	$HCOCH_3$	CH_2OHCHO	HC_7N			
CH^+	HCN	C_2H_2	CH_2CN	CH_3OH	NH_2CH_3		C_8H			
CN	HCO	CH_2D^+	CH_4	CH_3SH	c-C_2H_4O					
CO	HCO^+	HCCN	HC_3N	HC_3NH^+	CH_2CHOH					
CO^+	HCS^+	$HCNH^+$	HC_2NC	HC_2CHO						
CP	HOC^+	HNCO	HCOOH	NH_2CHO						
CSi	H_2O	HNCS	H_2CHN	C_5N						
HCl	H_2S	$HOCO^+$	H_2C_2O							
KCl	HNC	H_2CO	H_2NCN							
NH	HNO	H_2CN	HNC_3							
NO	MgCN	H_2CS	SiH_4							
NS	MgNC	H_3O^+	H_2COH^+							
NaCl	N_2H^+	NH_3								
OH	N_2O	SiC_3								
PN	NaCN									
SO	OCS									
SO^+	SO_2									
SiN	c-SiC_2									
SiO	CO_2									
SiS	NH_2									
CS	H_3^+									
HF	SiCN									
SH										

Detected cosmic Molecules in interstelar and circunstellar environment.

(adaptado de Wootten, A. 2001, http://www.cv.nrao/edu/-awootten)

Few Spectral lines



Observational spectra toward IRC+10216 e Orion-KL, between 330 e 360 GHz (Fonte: Groesbeck, T.D., Phillips, T.G., Blake, G. 1984, ApJSS, 94,147)

The Gas Between the Stars – Ronald Reynolds, Scientific American, 2002

Until few years ago:

The interstellar medium seemed a cold, static reservoir of gas.

Now its is recognized as a complex medium with a high diversity of temperature, density and ionization.

Supernova explosions blow giant bubbles; fountains and chimneys above the spiral disk.

Clouds are falling in, with high velocities, from beyond the disk (Maloney, Putman, 2003, ApJ, 589, 270)

Massive star formation → Heat and ionize the medium → Strong expansion

Important question →

Why the star formation activity change from one region to another,

Why there is sporadic star formation?

We know:H_2 glows at 2.2 µm and are located in dense gas in the Galactic plane.

Recently Far Ultraviolet Spectroscopic Explorer (FUSE) satellite sought for H_2 telltale absorption lines(0.1 µm) in the ultraviolet spectra. **(Blair&Savage, 2000)**

- H_2 was detected far outside the Galaxy (general astonishment !!)

High density is needed to shield the molecules from the ravage of the starlight. Are there neutral clouds far from the Galactic plane??

- Two new ionized HII components have been discovered: hot (10^6K) & warm (10^4K)

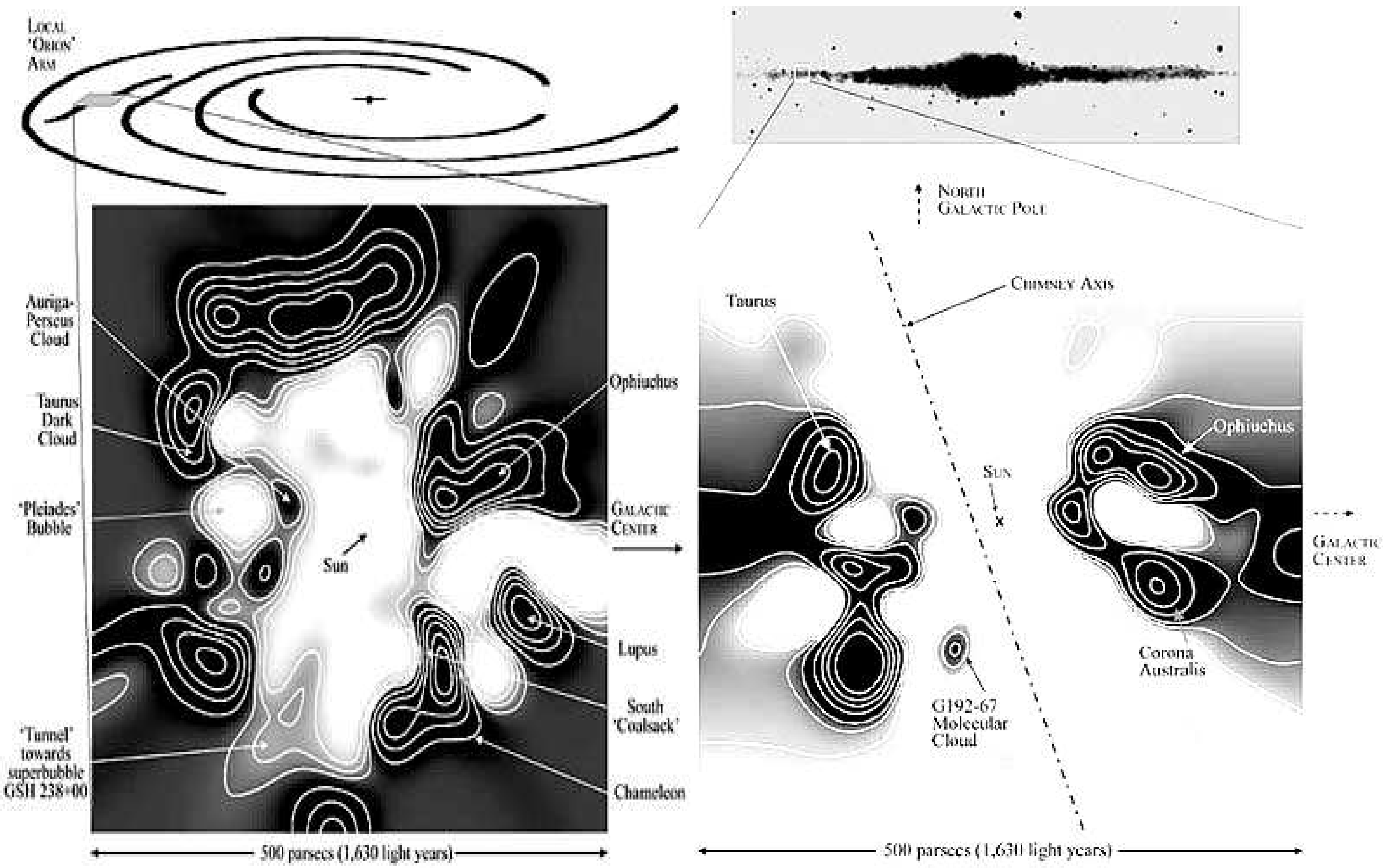
These phases stretch far above the galactic plane, forming a thick gaseous "halo" around the entire galaxy.

Hot phase – extend thousands of parsecs from the mid plane. This is not "interstellar" medium any more. This is our galaxy´s corona.

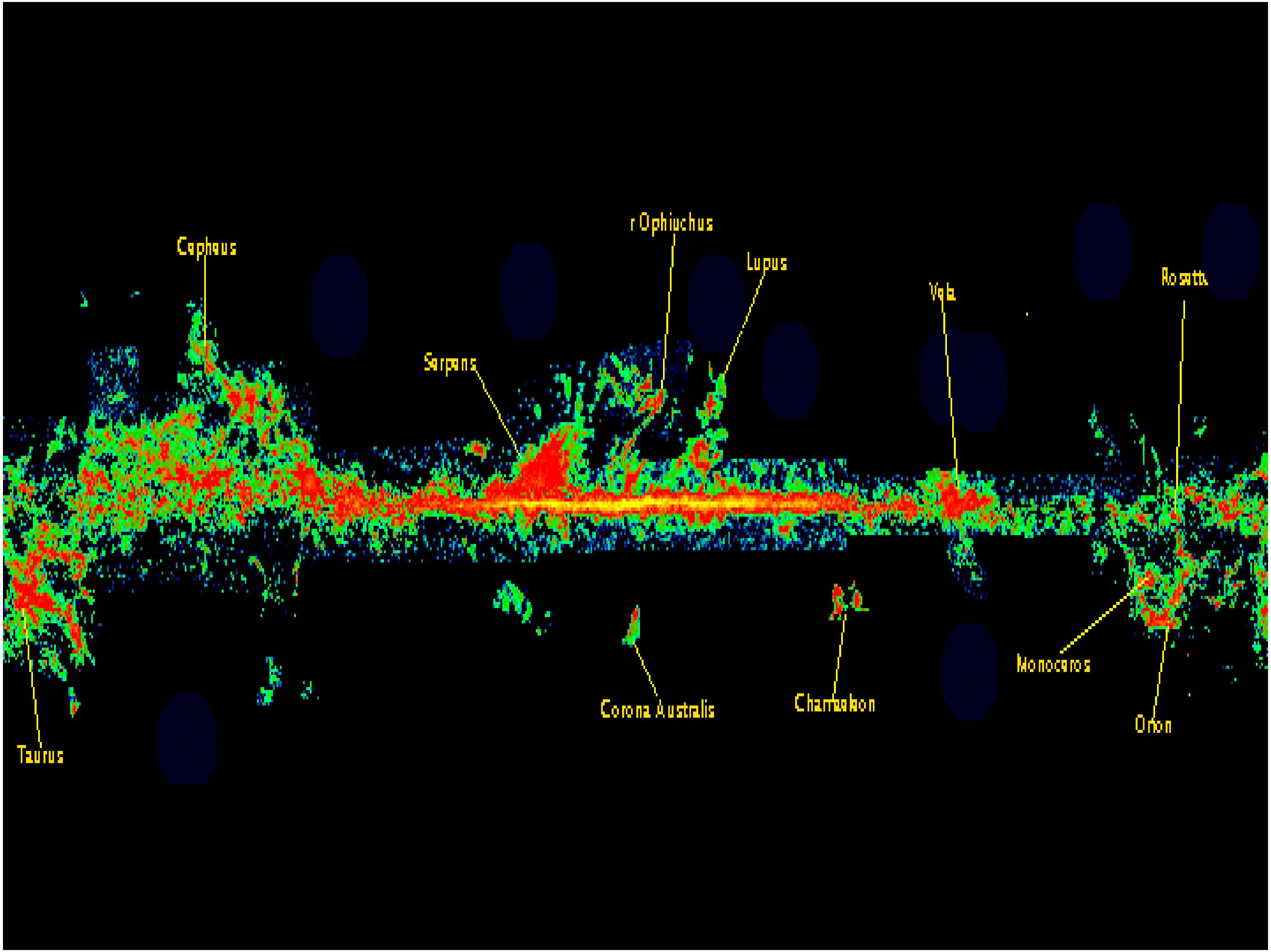
Note: →

It seems that O stars are the only known source of energy.

55% to 75% of the Int. medium is " hot" (Ostiker& Mckee, 1978)



Lallement et al. 2003;


r Ophiuchus
Cepheus
Lupus
Vela
Rosette
Serpens
Monoceros
Corona Australis
Chamaeleon
Orion
Taurus

SOURCE	DENSITY (m^{-3})	TEMPERATURE (K)
DIF NEBULA	$>10^{8}$	8000
DIF ATOMIC CLOUD	$3\ 10^{7}$	70
INTER-CLOUD GAS	$3\ 10^{5}$	6000
Gás mol. Frio	10^{9}-10^{10}	>10
Warm HI	$< 10^{4}$	$>5\ 10^{4}$
Hot HII	$<10^{4}$	10^{6}

SOURCE	***Mass (Solar M)***	***Average. Density (cm^{-3})***	***Tipical Size (pc)***	***Disper. Velocity (kms-1)***	***Exemplo***
Env. Giant. Star	0.1 - 5	10^{2} - 10^{5}	0.1 - 3	10 - 20	IRC10216
High Lat. Cloude	1 - 30	10- - 10^{3}	0.1 - 5	1 - 6	MBM - 12
Glóbulo Bok	1 - 100	10^{3} - 10^{5}	0.1 - 1	0.2 - 2	B335
Small dark Clouds	10 - 10^{3}	$2\ 10^{2}$ - 10^{4}	0.5 - 5	0.5 - 3	TMC-1
Comp. Small Clouds.	10^{3} - $5\ 10^{4}$	50 - 10^{3}	10 - 50	2 - 10	TOURO
Giant Mol. Clouds	$5\ 10^{4}$ - 10^{6}	50 - 10^{3}	20 - 150	5 -10	Orion
Centro Galáctico	10^{4} - 10^{7}	10^{4} - 10^{6}	10 - 50	20 - 50	Sgr B2

Bally, J. Proc. of ESO Workshop, 11 – 13, July, 1989)

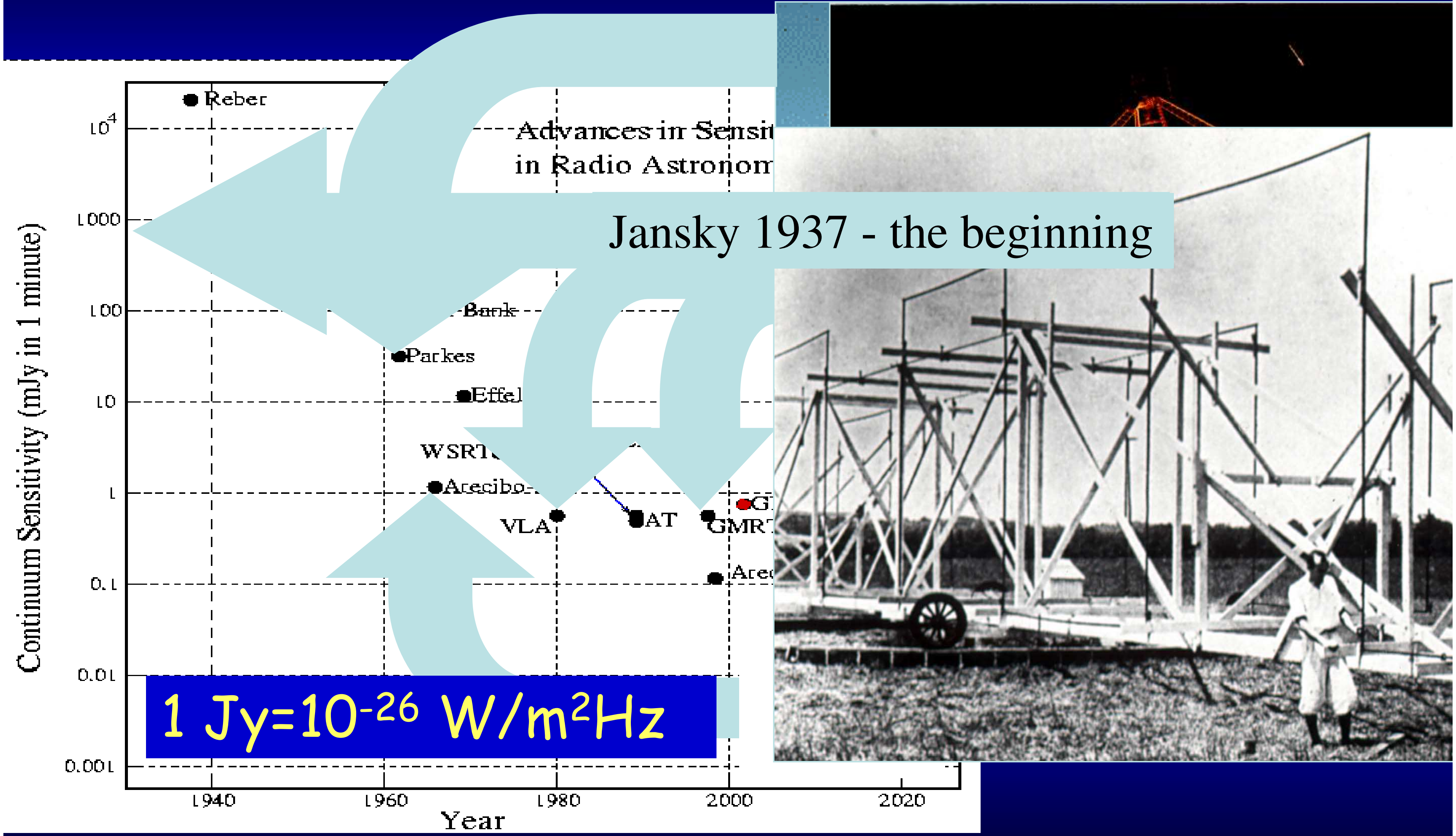
Why radio astronomy is important ?

Provide unique information about the Interstellar medium

- High space resolution image
- Diagnostic of *matter in different phases:*

  synchrotron radiation, maser emission, and bremsstrahlung from the thermal gas.
- Penetrate dust and gas which absorbs and scatters the radiation in other frequencies.
- Give information on magnetic field.

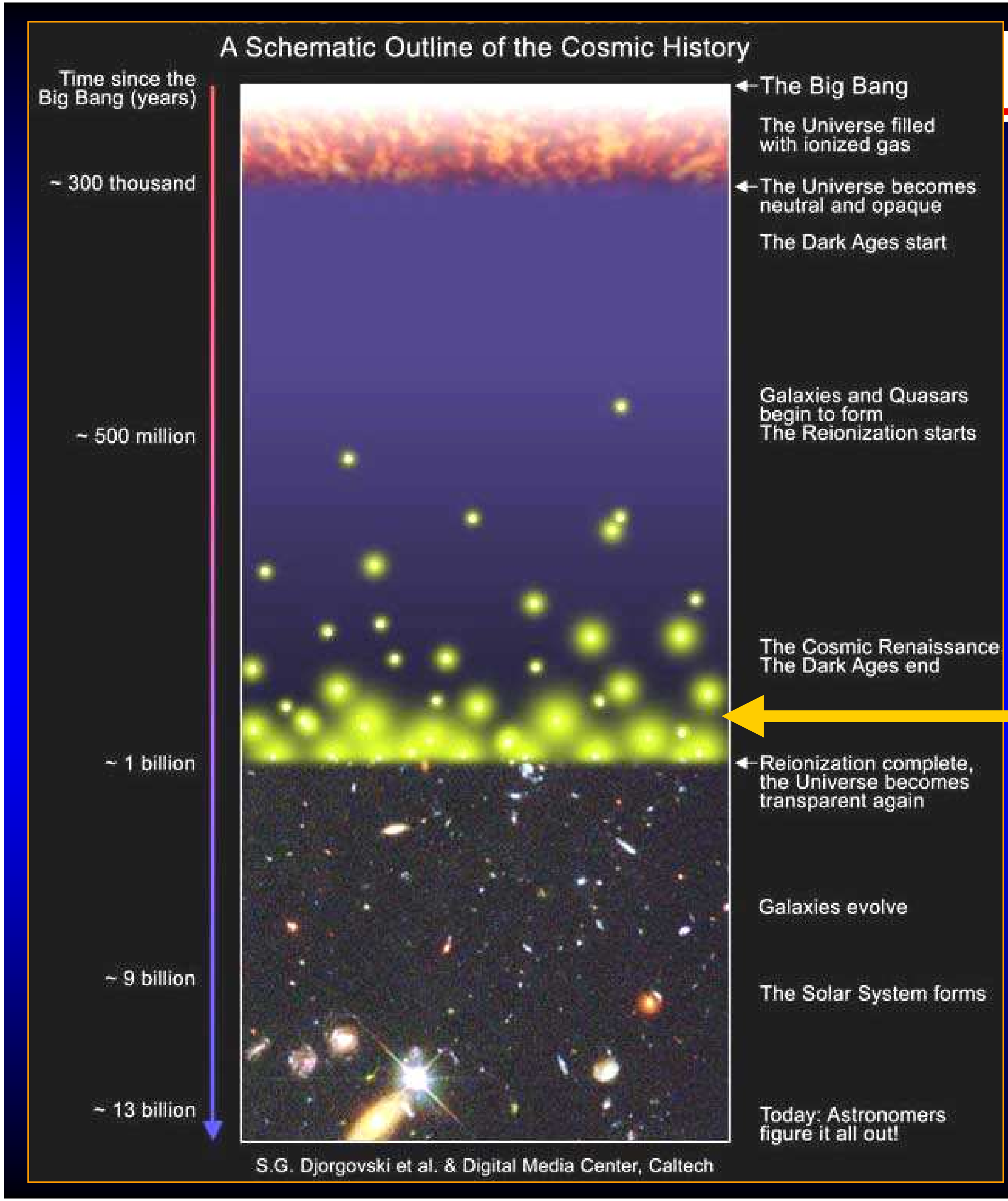
Advances of radio astronomy sensitivity.



Jansky 1937 - the beginning

1 Jy=10^{-26} W/m^{2}Hz

History of the IM

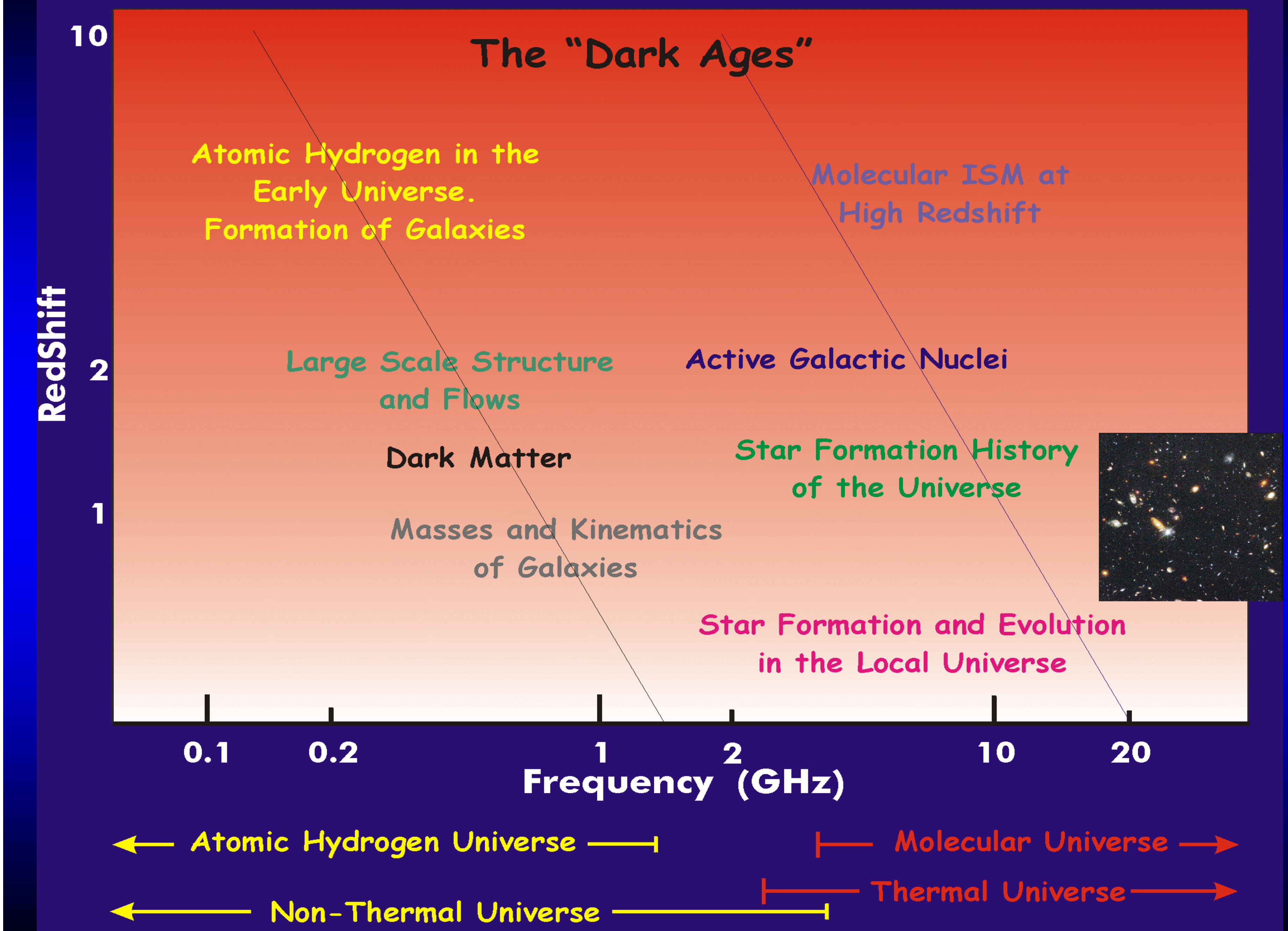


Epoch of Reionization (EoR)

- **Here the interstellar medium was born**

- **End of the ‘dark ages’**

Galaxy Evolution over Cosmic History



The "Dark Ages"

Atomic Hydrogen in the
Early Universe.
Formation of Galaxies

Molecular ISM at
High Redshift

Large Scale Structure
and Flows

Active Galactic Nuclei

Dark Matter

Star Formation History
of the Universe

Masses and Kinematics
of Galaxies

Star Formation and Evolution
in the Local Universe

← Atomic Hydrogen Universe —|

|— Molecular Universe →

|— Thermal Universe →

← Non-Thermal Universe —|

2 - Basic ideas about radiative transfer.

$$\frac{\partial I_\nu(T)}{\partial \tau} + ck.\nabla I_\nu = \text{sources} - \text{sink}$$

$$\frac{\partial I_\nu(T)}{\partial \tau} + ck.\nabla I_\nu = \frac{1}{4\pi}\rho j_\nu - \left(k_\nu^{abs} + k_\nu^{sca}\right)\rho I_\nu + \rho k_\nu^{sca} \int \Phi\left(k, k'\right) d\Omega$$

where ρ is mass density per volume
j_ν is emissivity per mass unity
k_ν^{abs} is the absorption cross section per mass unity
k_ν^{sca} is the opacity due to scattering.
$\phi\ (k, k')$ is probability density of scattering from k to k'.
c is light velocity.

If the radiation cross the cloud in a short time compared to the evolution time scale of the region

$$\frac{dI_\nu}{d\tau} = I_\nu - S_\nu(T)$$

where

$$S_\nu(k,x) = \frac{1}{k_\nu}\left(\frac{j_\nu}{4\pi} + k_\nu{}^{sca}\Phi_\nu\right)$$

$$\tau_\nu = \int_{s_0}^{s} \rho k_\nu ds$$

Using Einstein´s coefficients:

$$\frac{dI_\nu(T)}{\frac{h\nu\Phi_\nu}{4\pi}\left(N_1B_{12} - N_2B_{21}\right)ds} = \frac{2h\nu^3}{c^2}\frac{1}{\left(\frac{N_1}{N_2} - 1\right)} - I_\nu(T)$$

$$\Downarrow \qquad\qquad \Downarrow$$

$$\tau_\nu = \int kds = \int \left(N_1B_{12} - N_2B_{21}\right)\Phi_\nu \frac{h\nu}{4\pi}ds \qquad\qquad S\nu$$

If the populations of the l fol D nn
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Tex is a measure of the efficiency of the excitation mechanism.

$$N_1\left(\gamma_{12} + B_{12}\right.$$

$$\frac{N_2 g_1}{N_1 g_2} = e^{-\left(\frac{T_0}{T_{ex}}\right)} = e^{-\left(\frac{T_0}{T_b}\right)} \frac{A_{21} + C_{21} e^{-\left(\frac{T_0}{T_K}\right)} \left[e^{\left(\frac{T_0}{T_b}\right)} - 1 \right]}{A_{21} + C_{21}\left(1 - e^{\left(-\frac{T_0}{T_b}\right)}\right)}$$

where C_{21} is the number of transitions per volume and γ_{21} is the transition probability due to collisions. T_K and T_b are kinetic temperature of the gas and brightness temperature of the radiation field respectively.

Radio observations

From the previous equations it is easy to show that the temperature observed with a radio telescope can be written:

$$T_{A,\nu} = \eta_{a,\nu} T_{bg} \frac{\Omega_{0,\nu}}{\Omega} \quad {}^{-\tau_\nu(s)} \quad \Omega_{s,\nu} \left(1 \quad {}^{-\tau_\nu(s)}\right)$$

$$T_A = \overline{T_{ex}} \left(1\right.$$

where $\eta_{a,\nu}$ is the ra

T_{bg} is back g

$T_{ex,\nu}$ is the e

Ω_A is the ra

$\Omega_{i,\nu}$ is the so

$T_{A,\nu}$ is the an

MASERS: main characteristic: T_b □ 1

[Ex. $T_b(H_2O) > 10^{12}$ K]

If $T_b >> 1$ than $e^{-\tau} = \frac{-T_b}{T_{ex}}$ and $e^{-\tau} >> 1$

This is possible if $\tau_\nu < 0 \Rightarrow \left(N_1 B_{12} - N_2 B_{21}\right) < 0$

and $N_2 > N_1$

4.2- Parameters of the clouds derived from radio lines

What are the substances and radio transitions to study a cloud ?

- It depends on the properties of the region.
- Molecular abundance
- Available receivers and atmospheric transparency
- In a very near future, the choice of the radio bands without noise due to telecommunication services, will be important.

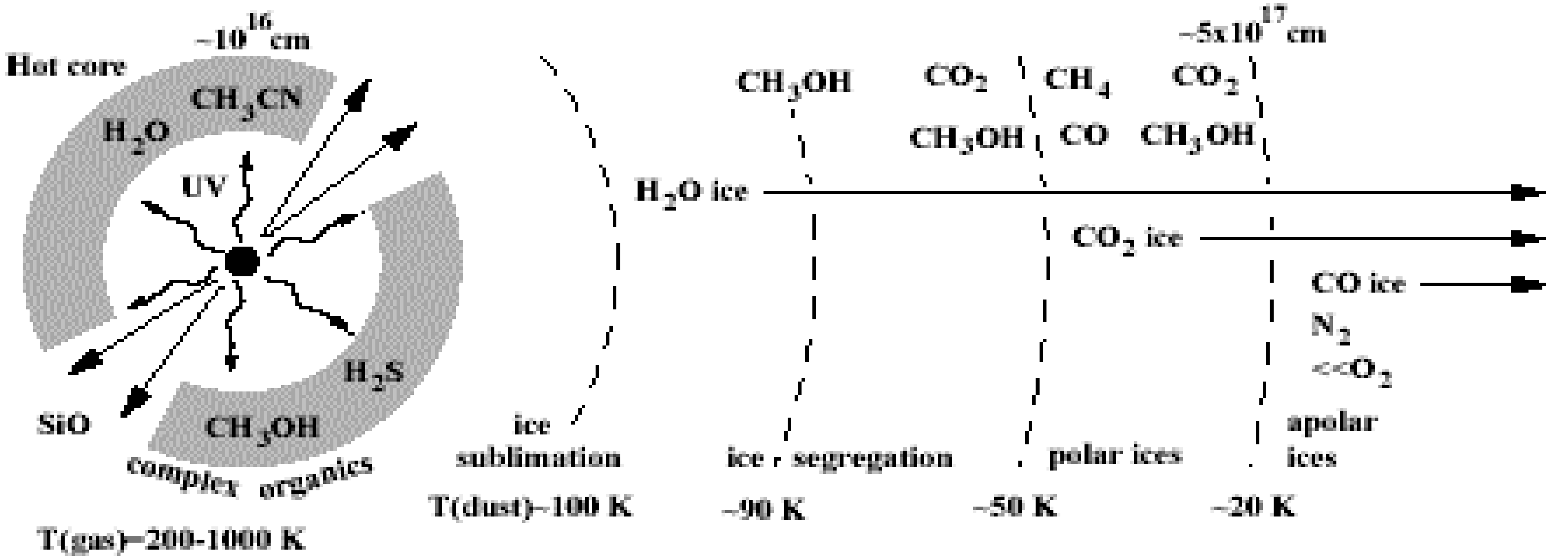
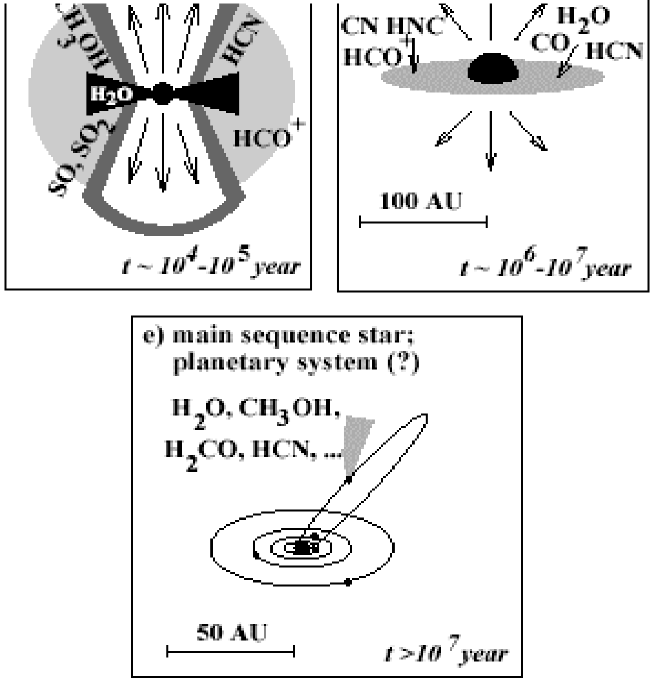
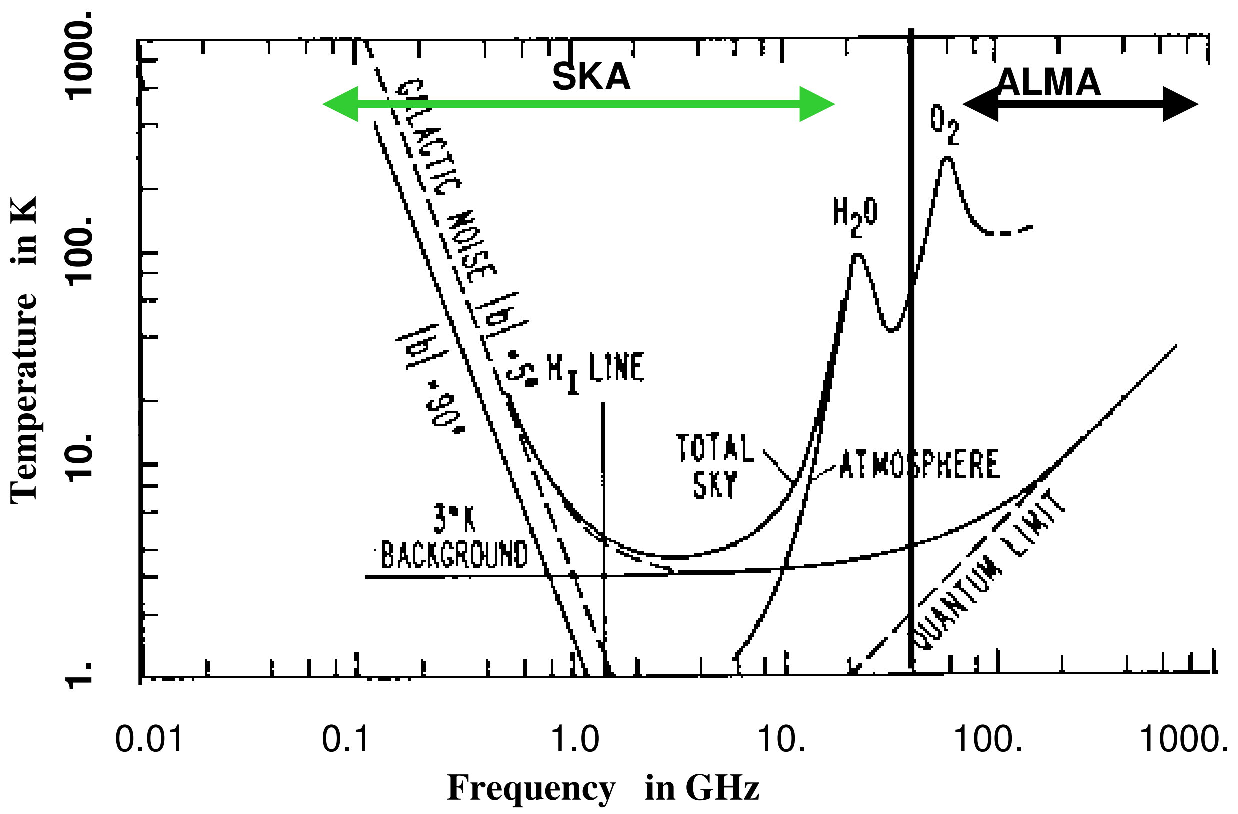


Fig. Schematic illustration of the physical and chemical environment of massive Young stellar Objects. (Vandishoeck and Hogerheijde, 1999)

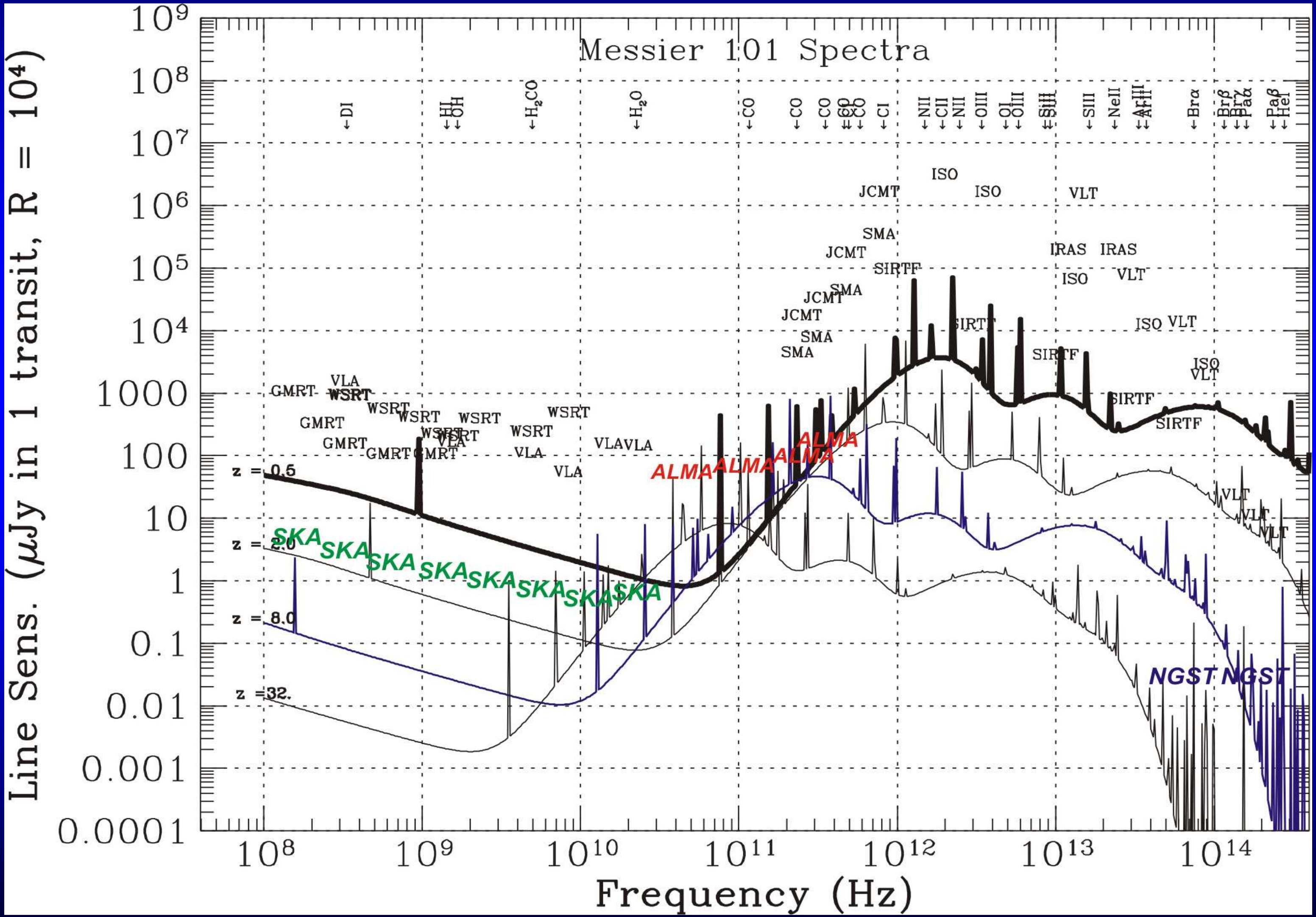


A schematic view of the characteristic molecules at different stages of low-mass star formation. (a) dark cloud core, (b) collapse stage, (c) deeply embedded YSO phase, (d) Young T Tauri star, (e) Mature planetary system with icy bodies such as comets

Atmospheric transparency



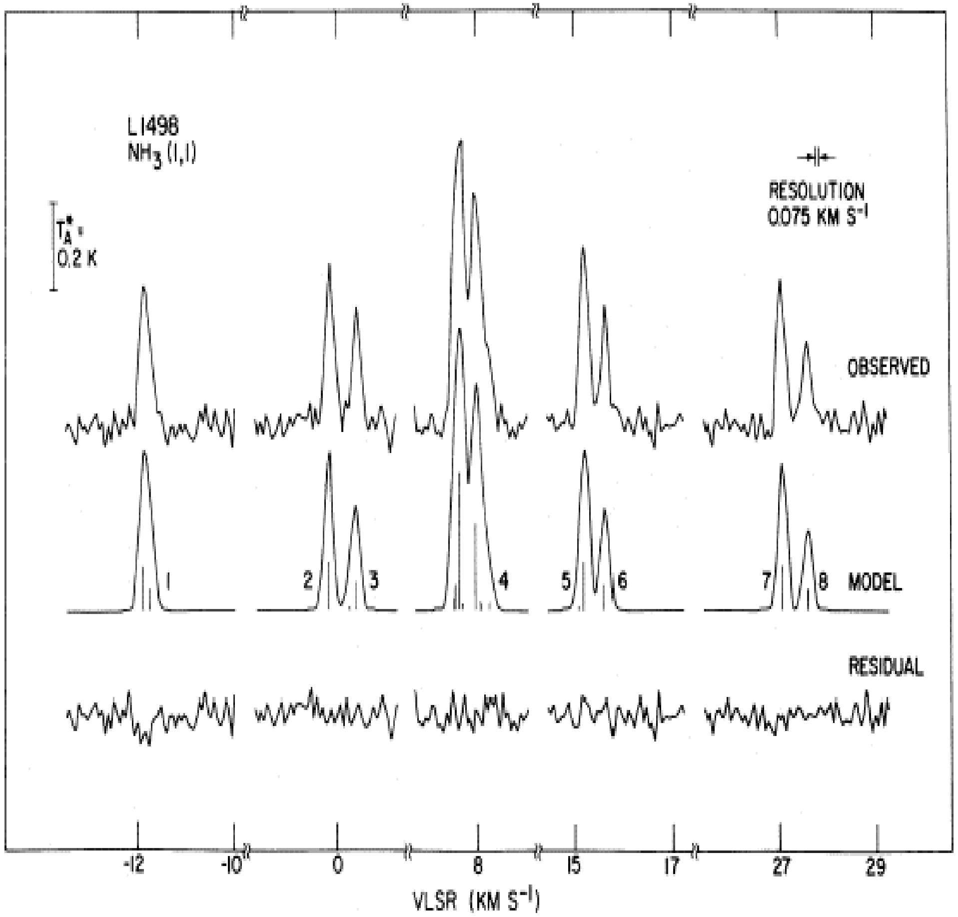
Transitions, telescope and spectral lines



4.2.1- From radio observations

It is possible:

- Calculate, from transitions that are observed only under the conditions of the Interstellar medium, properties of the molecular species.

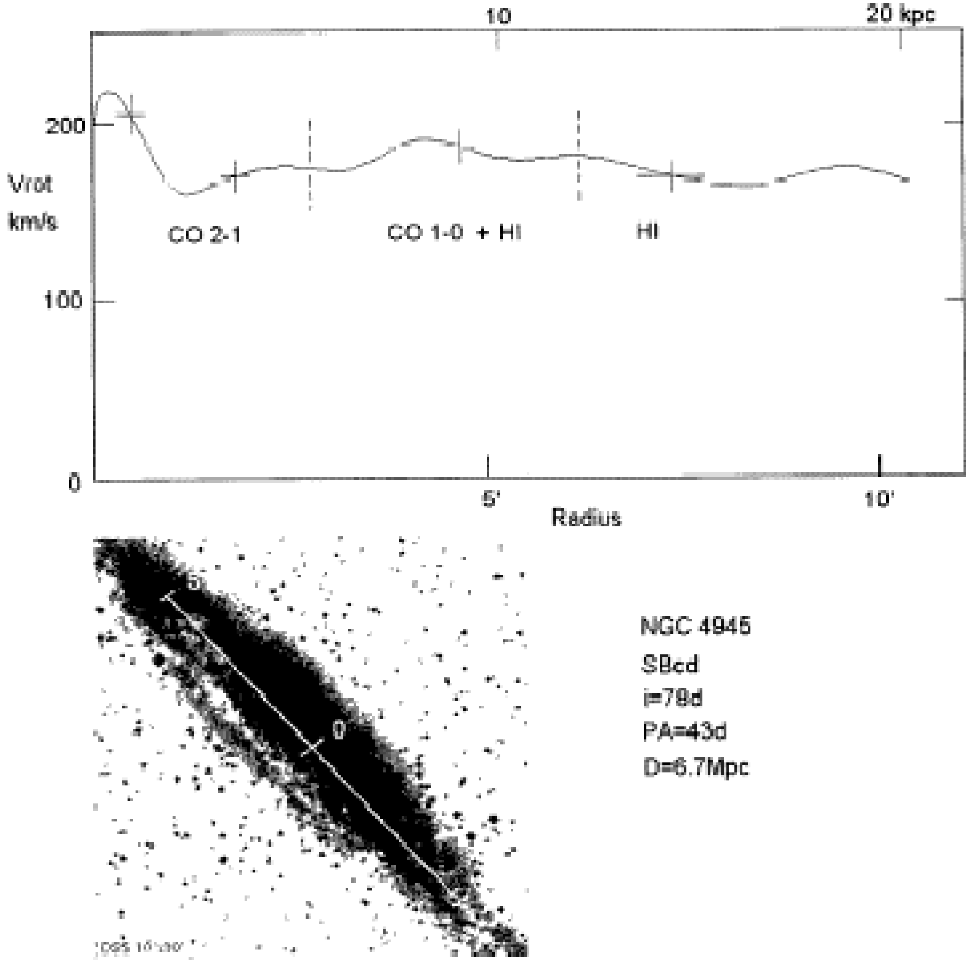


NH_3 (1,1) spectra observed toward L1498. (Fonte: Myers,P.C., Benson, P.J. 1983, ApJ, 266, 309).

4.2.1- From radio observations

It is possible:

- Measure cinematic of the clouds in **large** and small scale.

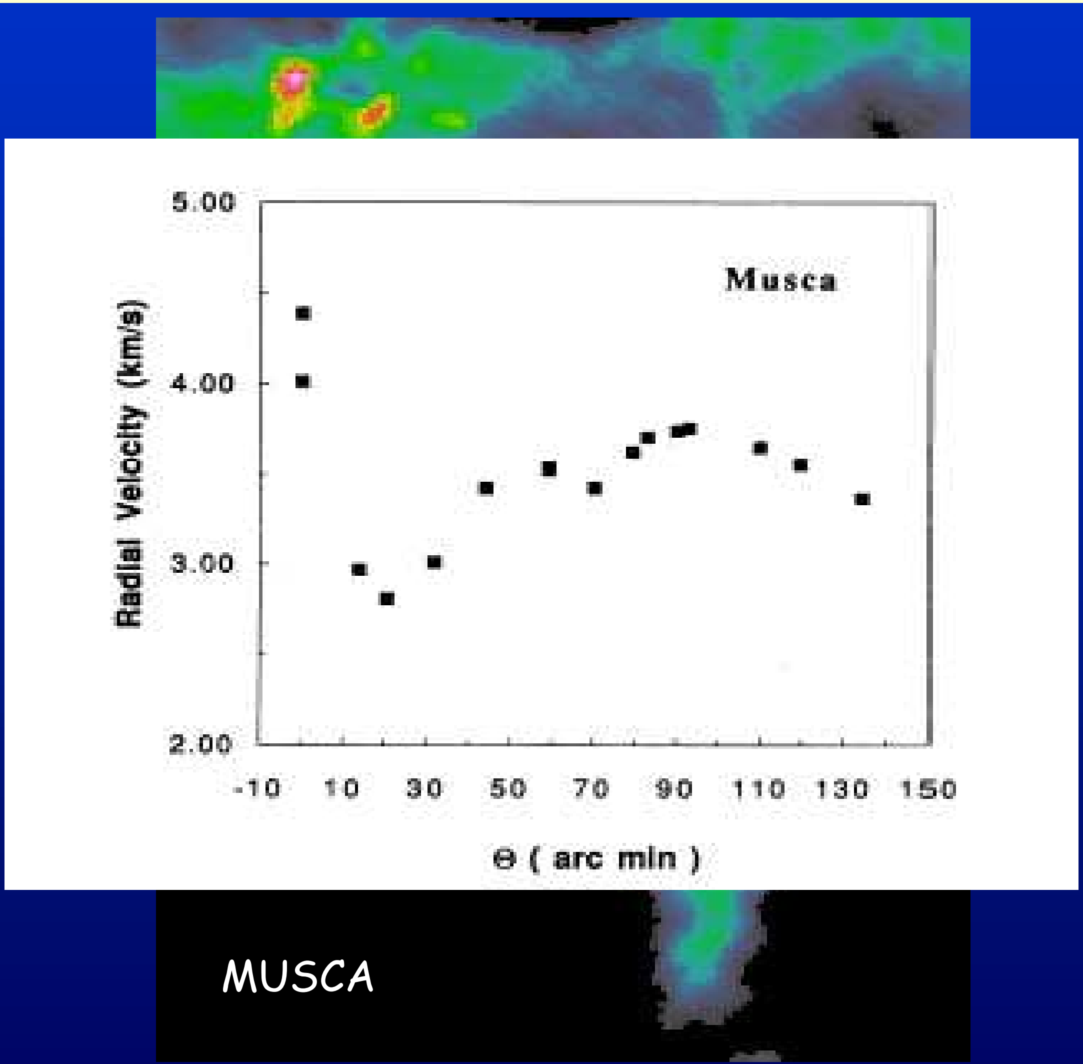


NGC 4945 rotation curve. High resolution position-velocity diagram obtained from of CO and HI lines. (Sofue, Y., 1997, PASJ, 49, 17)

4.2.1- From radio observations

It is possible:

- Measure cinematic of the clouds in large and **small** scale.



Observatin of ^{13}CO(1-0) toward the Musca filament (Vilas-Boas, Myers, Fuller, 1994)

Parameters derived from a simple model

Column Density (cm^{-2})

Using the opacity definition given before, the populations ratio of the levels given by the Boltzmann equation, and $\Phi_\nu = 1/\Delta\nu$ the optical depth of a linear rotor transition (J=1-0) is:

$$\tau_{\nu_o} = 1.29\times10^{-13}\,\frac{N_J\left(cm^{-2}\right)}{\Delta V\left(kms^{-1}\right)}\left(\frac{\mu_{rot}}{Debye}\right)^2\frac{J}{2J+1}\left(e^{\frac{h\nu}{kT_{ex}}}-1\right)$$

We need to know N_{TOT} (cm^{-3}). According to Townes and Shawlow (1972):

$$N_J = \frac{hB_{rot}}{kT_{ex}}(2J+1)\left(e^{\frac{-Ej}{kT_{ex}}}\right)N_{tot}$$

$$\tau_{\nu_o} = 5.95\times10^{-16}\,\frac{\left(N_{tot}/cm^{-2}\right)}{\left(\Delta V/kms^{-1}\right)}\left(\frac{\mu_{rot}}{Debye}\right)^2\left(\frac{B_{rot}}{GHz}\right)^2\left(\frac{J^2}{T_{ex}^2}\right)$$

Parameters derived from a simple model

Optical depth

Observing two transitions of the same molecule or transitions of different isotopic specie, the ratio of their antenna temperature is

$$\frac{T_a^{(J=1-0)}}{T_a^{(J=2-1)}} = \frac{\overline{T_{ex}}^{(J=1-0)}}{\overline{T_{ex}}^{(J=2-1)}} \frac{\left(1 - e^{-\tau^{(J=1-0)}}\right)}{\left(1 - e^{-\tau^{(J=2-1)}}\right)}$$

or

$$\frac{T_a^{(J=1-0)}(CO)}{T_a^{(J=1-0)}\left({}^{13}CO\right)} = \frac{\overline{T_{ex}}^{(J=1-0)}(CO)}{\overline{T_{ex}}^{(J=1-0)}\left({}^{13}CO\right)} \frac{\left(1 - e^{-\tau(CO)}\right)}{\left(1 - e^{-\tau\left({}^{13}CO\right)}\right)}$$

Parameters derived from a simple model

Kinetic temperature

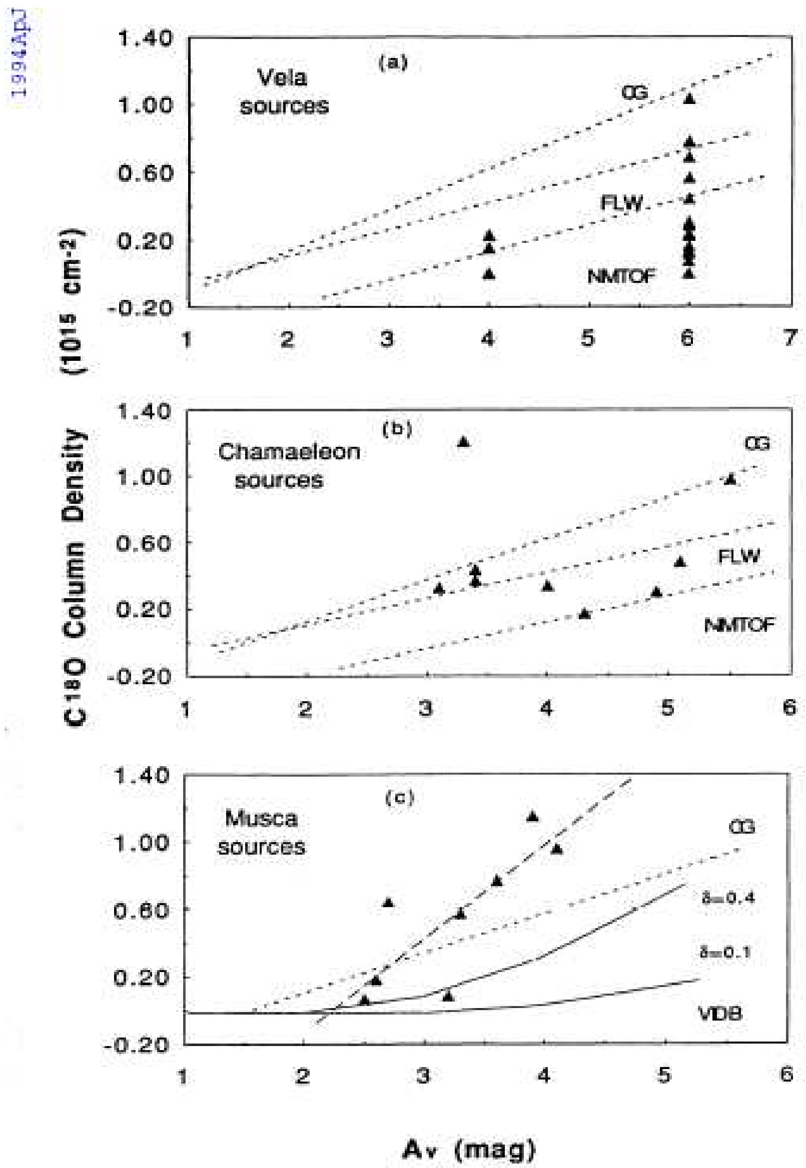
Using the expression for the optical depth, we can write de equations:

$$\frac{\tau^{m}}{\tau^{n}} = = e^{-\frac{h\nu(m,n)}{kT_{ex}}} \frac{\Delta V^{n}}{\Delta V^{m}} \left(\frac{A^{m}_{ul} \nu_{n}^{3}}{A^{n}_{ul} \nu_{m}^{3}} \right)$$

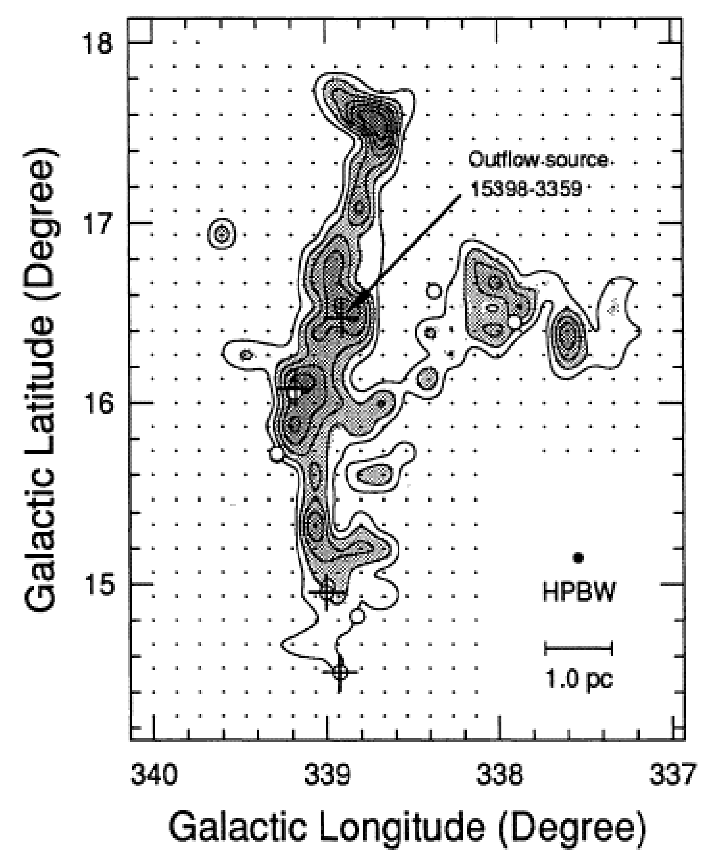
$$T_{ex} = \frac{\frac{h\nu(m,n)}{k}}{-\ln\left\{ \frac{\tau^{m}}{\tau^{n}} \frac{\Delta V^{m}}{\Delta V^{n}} \left(\frac{A^{n}_{ul} \nu_{m}^{3}}{A^{m}_{ul} \nu_{n}^{3}} \right) \right\}}$$

$$T_{ex} = T_{K} = \frac{\frac{h\nu(m,n)}{k}}{-\ln\left\{ \frac{-\ln\left[1 - \frac{T_{a}^{m}}{T_{a}^{n}} \left(1 - e^{-\tau^{n}}\right) \right]^{m}}{\tau^{n}} \frac{\Delta V^{m}}{\Delta V^{n}} \left(\frac{A^{n}_{ul} \nu_{m}^{3}}{A^{m}_{ul} \nu_{n}^{3}} \right) \right\}}$$

Parameters derived from a simple model

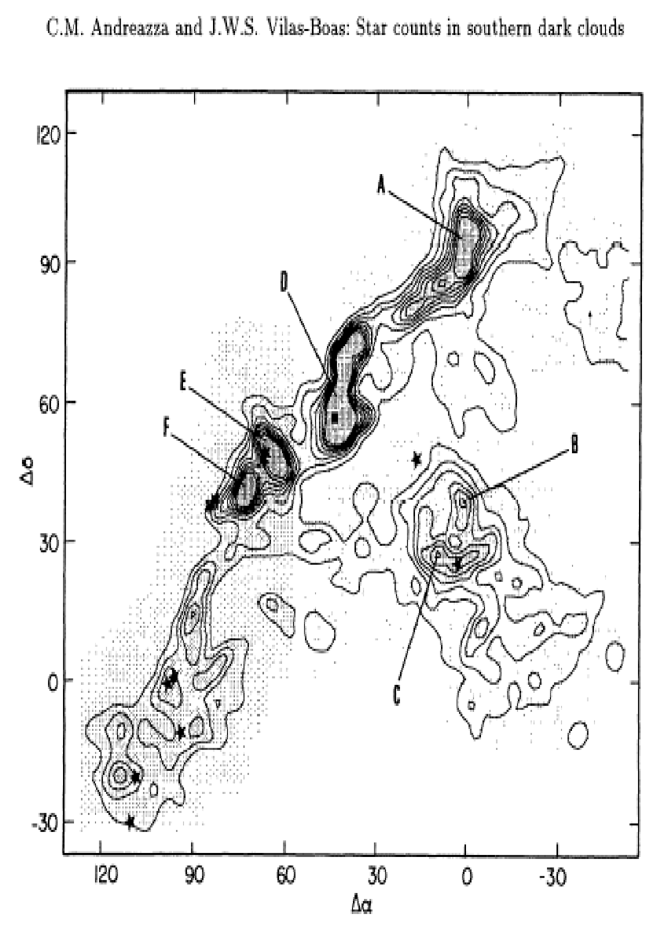


Vilas-Boas, et al, 94



Tachihara et al, 1996

^{13}CO (J=1-0)



Andreazza, Vilas Boas, 1996

Star counts Visual

Parameters derived from a simple model

Mass

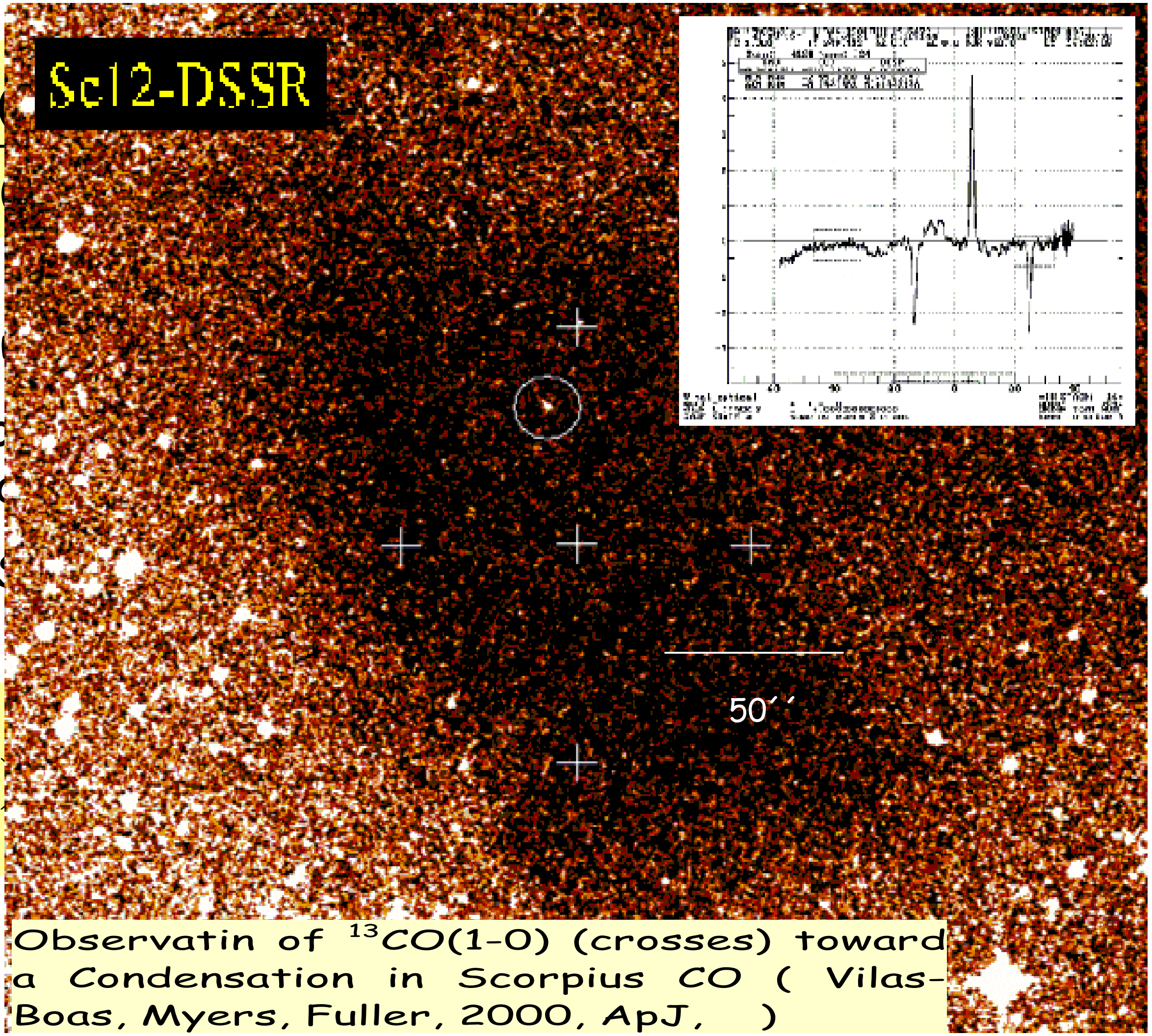
$$M\ (M_{\square}) = 22,2 \Bigg[\frac{N(}{10^{21}(}$$

Where N(H_2) is the col

R is the radius o
of the source o

(ex. Digitized S

$$M_{Vir} \cong 210 (M_{\square}$$



Observatin of ^{13}CO(1-0) (crosses) toward a Condensation in Scorpius CO (Vilas-Boas, Myers, Fuller, 2000, ApJ,)

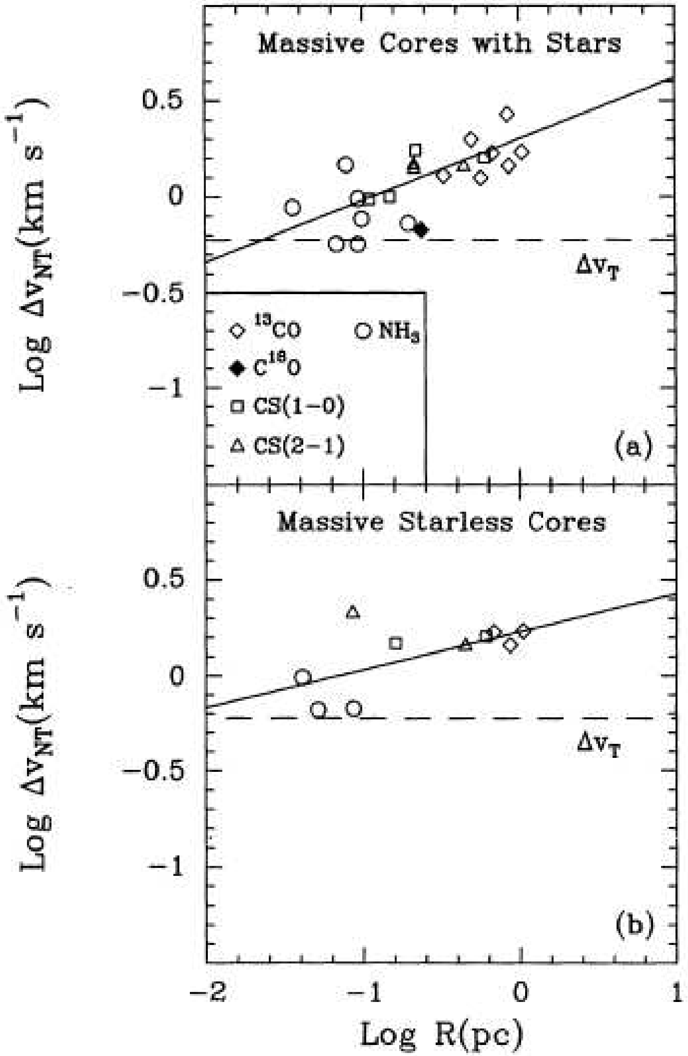


FIG. 12.—Line width–size relation in *(a)* eight Orion massive cores associated with an *IRAS* source, and *(b)* three starless cores in Orion. Dashed lines represent the thermal part of the line width of the molecule of mean mass, assuming temperature 18 K. The two relations do not show any significant difference.

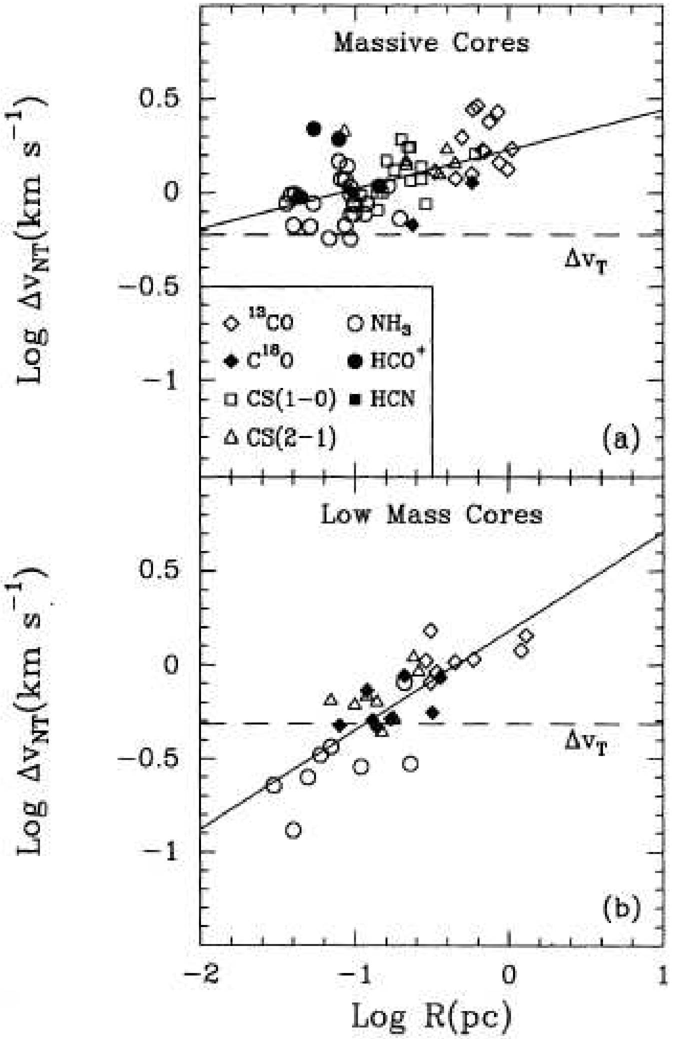


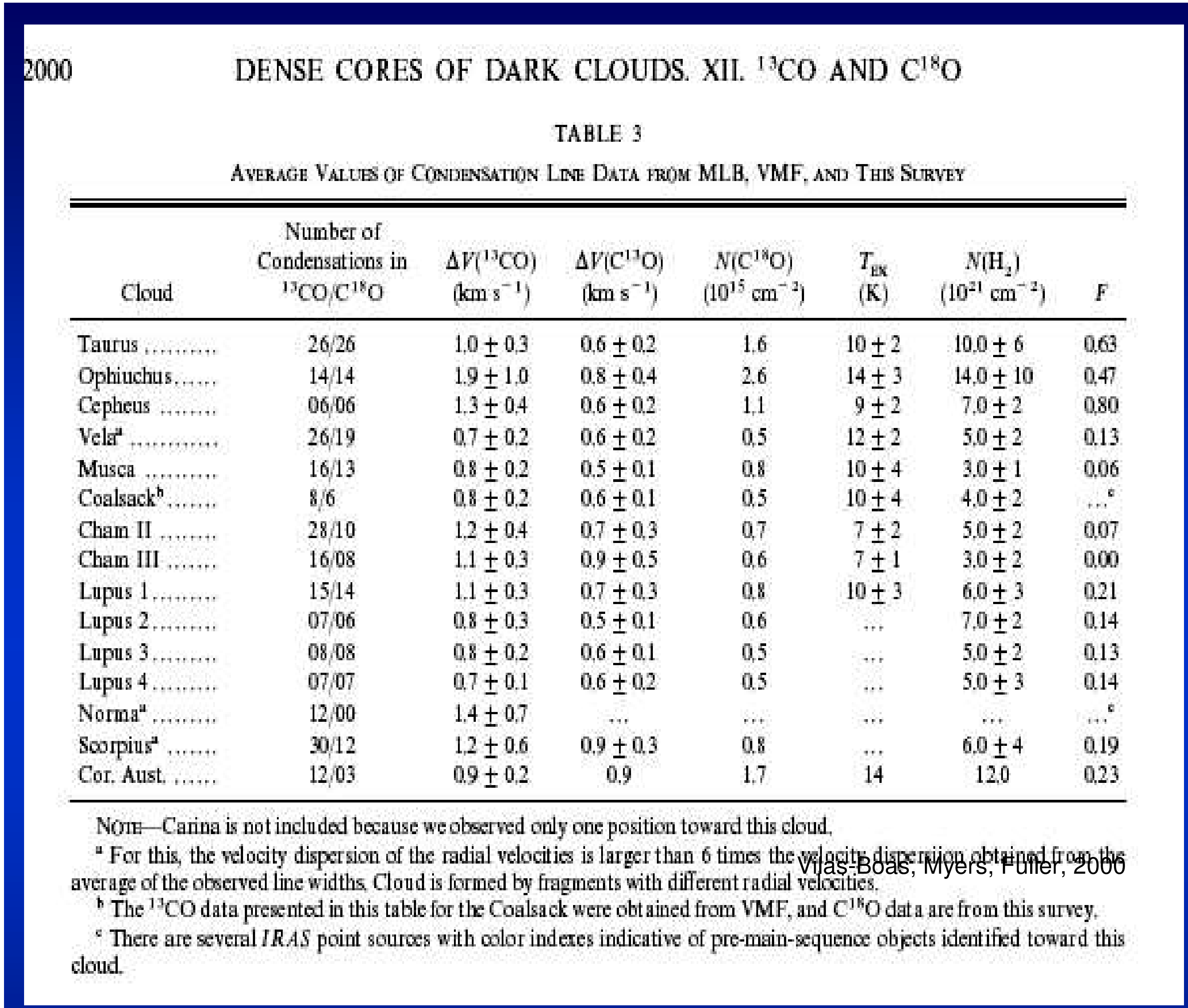
FIG. 6.—Line width–size relation in *(a) massive* cores in Orion, and *(b) low-mass* cores in Perseus, Taurus, Orion, Ophiuchus, and Cepheus. Dashed lines labeled Δv_T represent the thermal part of the line width of the molecule of mean mass, assuming temperature 18 K (massive cores), or 10 K (low-mass cores). The positions of ammonia cores in these Δv–R diagrams play a crucial role in determining differences between massive and low-mass cores (see text).

Caselli, Myers. 1995

^{13}CO and $C^{18}O$ (J=1-0) observations toward dark clouds.

- Chamaeleon, Musca, Coalsack, Lupus, Corona Australis, Vela and Scorpius

  Vilas-Boas, Myers e Fuller (1994, 2000)
  - SEST, 15 m telescope (Booth et al. 1992)
- Taurus, Cepheus, Ophiuchuc.
  - Myers, Linke and Bensons (MLB, 1983)
  - Bell Lab, 7 m telescópio (MLB)
- Ophiuchus North.
  - Nozawa et al (1973)
  - Nagoya 4 m telescope (Kawabata et al. 1989)
- **Cirrus de alta latitude**
  - Turner e Richard (1992). (Turner et al, 1992)
  - NRAO 12 m telescope (Turner et al. 1992)



2000 DENSE CORES OF DARK CLOUDS. XII. ^{13}CO AND C^{18}O

TABLE 3

AVERAGE VALUES OF CONDENSATION LINE DATA FROM MLB, VMF, AND THIS SURVEY

Cloud	Number of Condensations in ^{13}CO/C^{18}O	$\Delta V(^{13}CO)$ (km s^{-1})	$\Delta V(C^{13}O)$ (km s^{-1})	$N(C^{18}O)$ (10^{15} cm^{-2})	T_{EX} (K)	$N(H_2)$ (10^{21} cm^{-2})	F
Taurus	26/26	1.0 ± 0.3	0.6 ± 0.2	1.6	10 ± 2	10.0 ± 6	0.63
Ophiuchus......	14/14	1.9 ± 1.0	0.8 ± 0.4	2.6	14 ± 3	14.0 ± 10	0.47
Cepheus	06/06	1.3 ± 0.4	0.6 ± 0.2	1.1	9 ± 2	7.0 ± 2	0.80
Vela[a]	26/19	0.7 ± 0.2	0.6 ± 0.2	0.5	12 ± 2	5.0 ± 2	0.13
Musca	16/13	0.8 ± 0.2	0.5 ± 0.1	0.8	10 ± 4	3.0 ± 1	0.06
Coalsack[b].......	8/6	0.8 ± 0.2	0.6 ± 0.1	0.5	10 ± 4	4.0 ± 2	...[c]
Cham II	28/10	1.2 ± 0.4	0.7 ± 0.3	0.7	7 ± 2	5.0 ± 2	0.07
Cham III	16/08	1.1 ± 0.3	0.9 ± 0.5	0.6	7 ± 1	3.0 ± 2	0.00
Lupus 1.........	15/14	1.1 ± 0.3	0.7 ± 0.3	0.8	10 ± 3	6.0 ± 3	0.21
Lupus 2.........	07/06	0.8 ± 0.3	0.5 ± 0.1	0.6	...	7.0 ± 2	0.14
Lupus 3.........	08/08	0.8 ± 0.2	0.6 ± 0.1	0.5	...	5.0 ± 2	0.13
Lupus 4.........	07/07	0.7 ± 0.1	0.6 ± 0.2	0.5	...	5.0 ± 3	0.14
Norma[a].........	12/00	1.4 ± 0.7	...	...	...	...	...[c]
Scorpius[a]	30/12	1.2 ± 0.6	0.9 ± 0.3	0.8	...	6.0 ± 4	0.19
Cor. Aust.	12/03	0.9 ± 0.2	0.9	1.7	14	12.0	0.23

NOTE—Carina is not included because we observed only one position toward this cloud.

[a] For this, the velocity dispersion of the radial velocities is larger than 6 times the velocity dispersion obtained from the average of the observed line widths. Cloud is formed by fragments with different radial velocities.

[b] The ^{13}CO data presented in this table for the Coalsack were obtained from VMF, and C^{18}O data are from this survey.

[c] There are several *IRAS* point sources with color indexes indicative of pre-main-sequence objects identified toward this cloud.

Vilas-Boas, Myers, Fuller, 2000

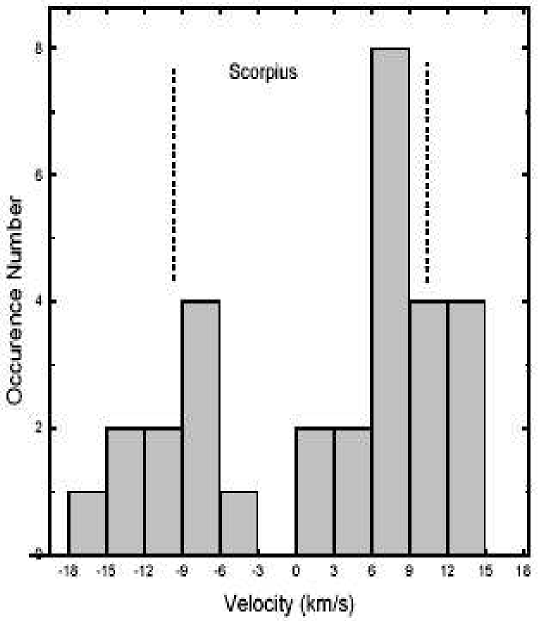
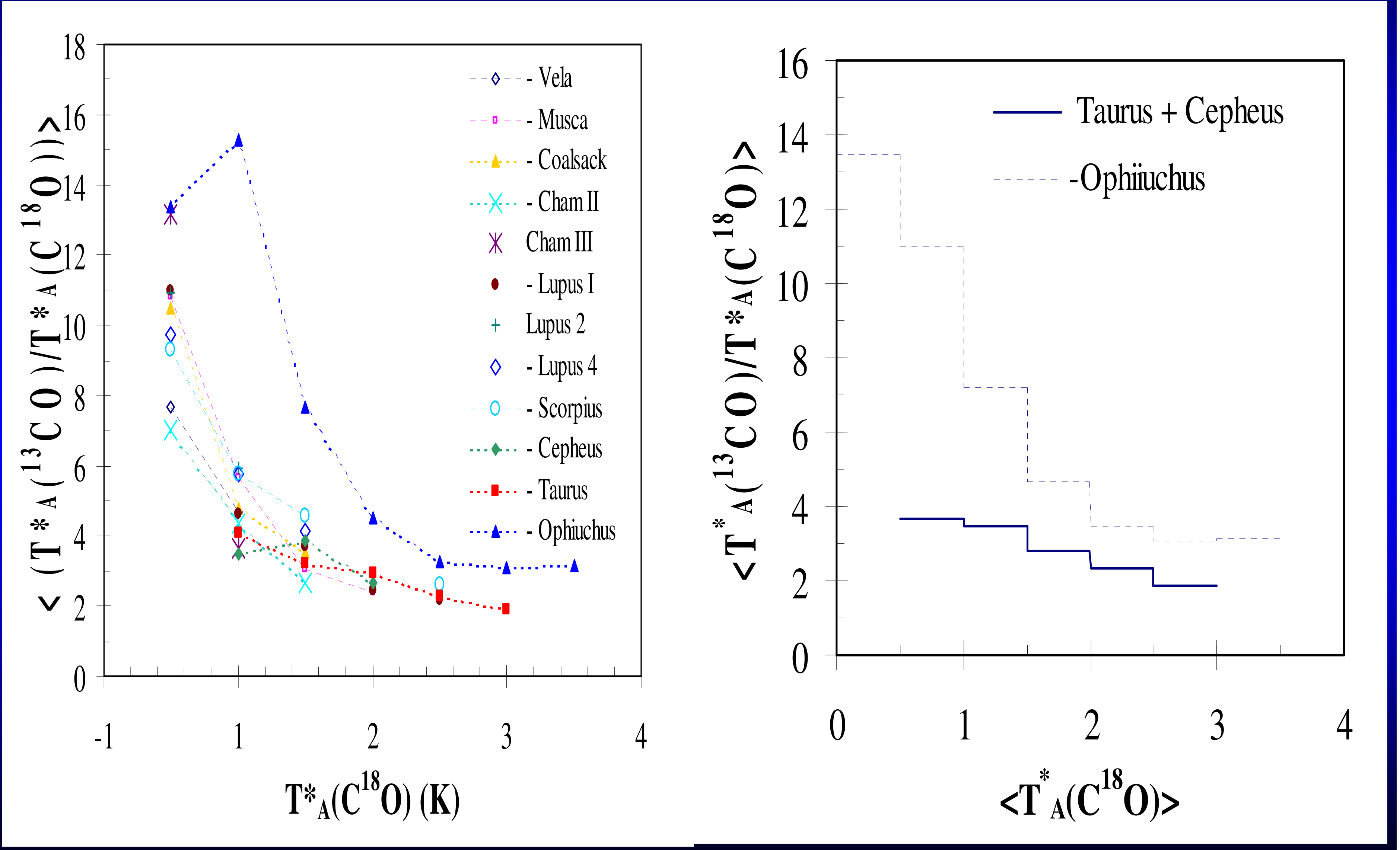
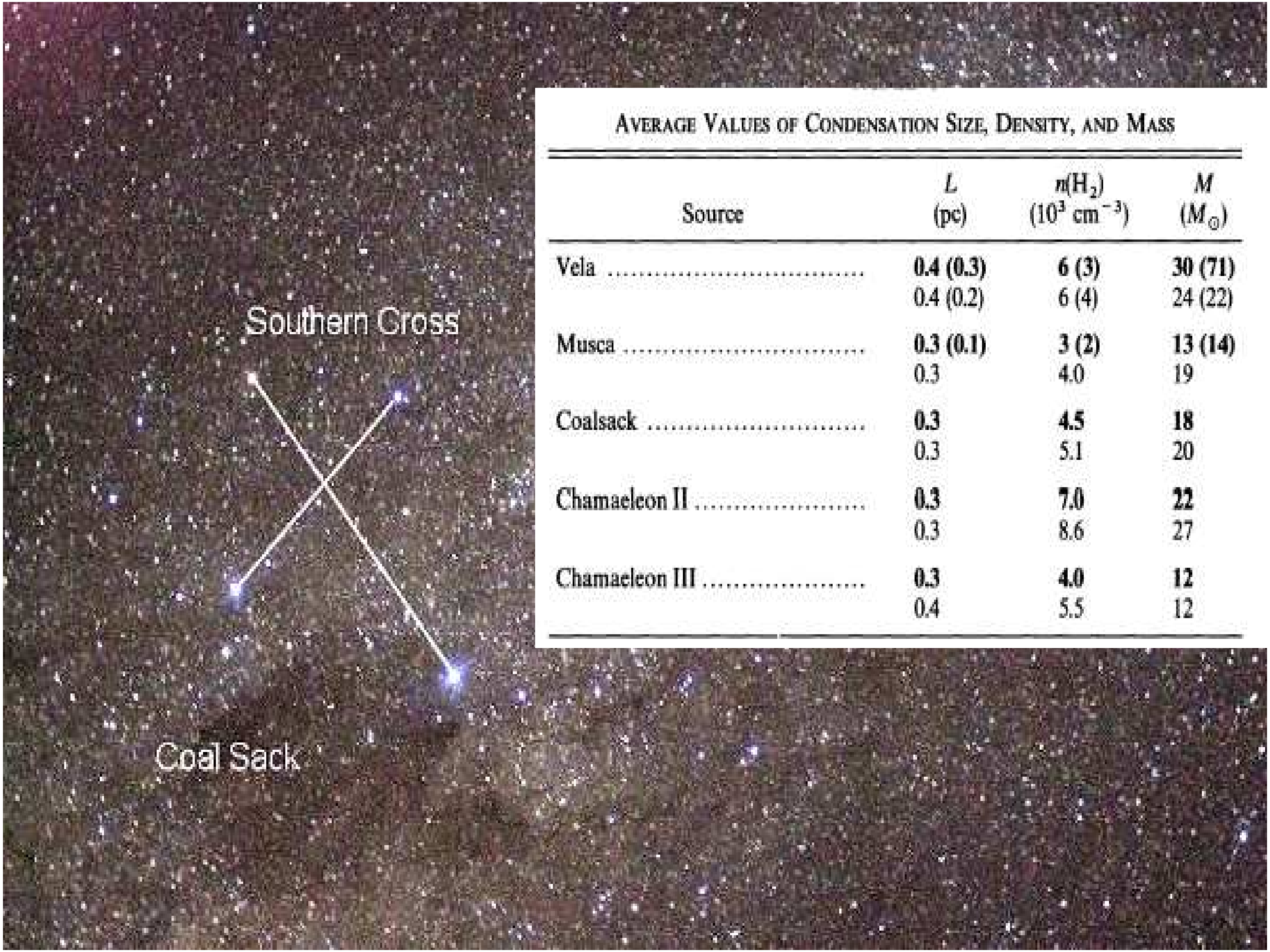


FIG. 4.—Histogram of the radial velocity distribution observed toward Scorpius. Two peaks with radial velocities around −7.5 and 7.5 km s^{-1} are seen. The dotted lines show a model of an expanding ring with an expansion velocity of 10 km s^{-1} (de Geus 1988).

Vilas Boas, Hickel, Kahn, 2004

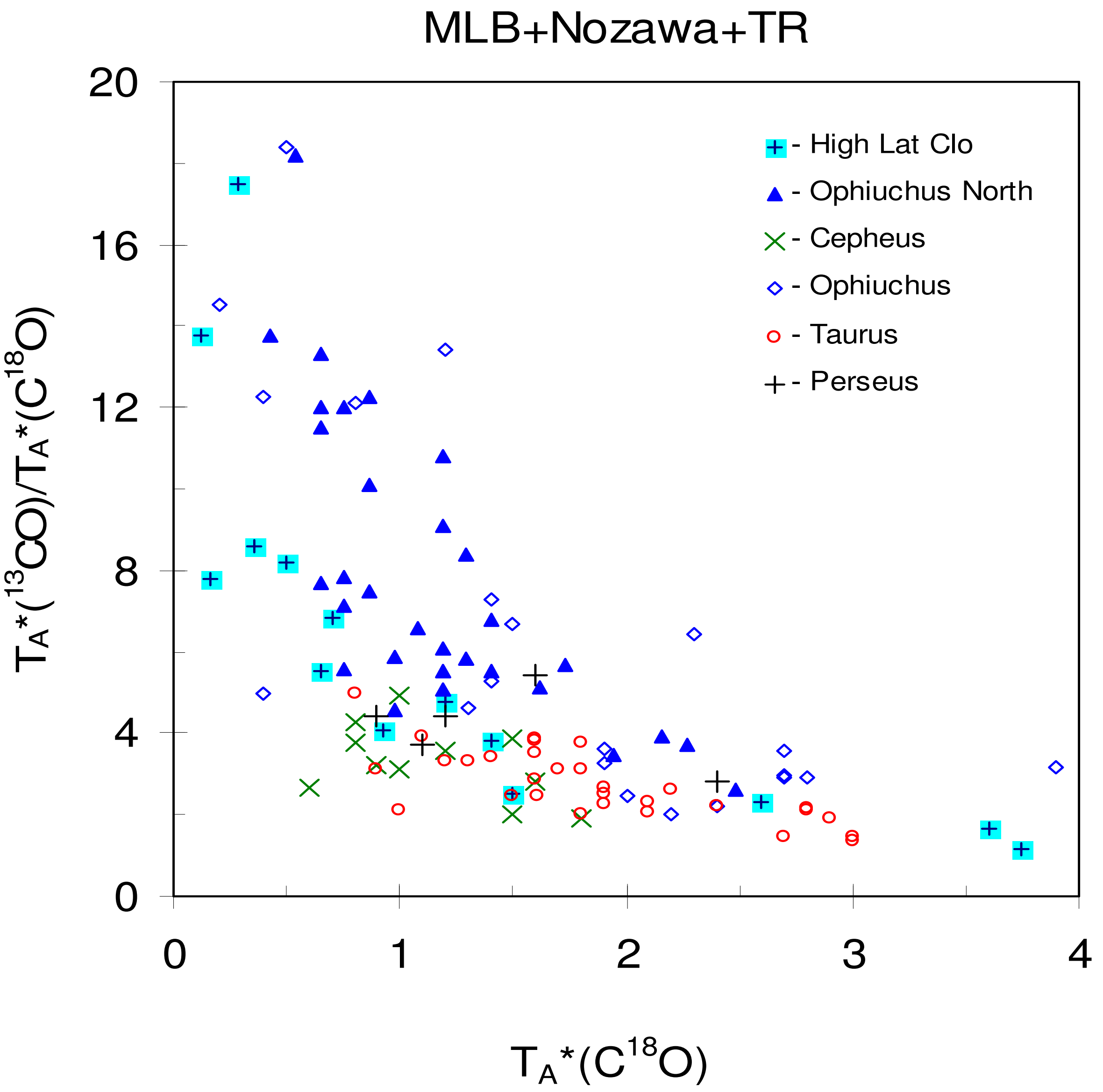
All condensations



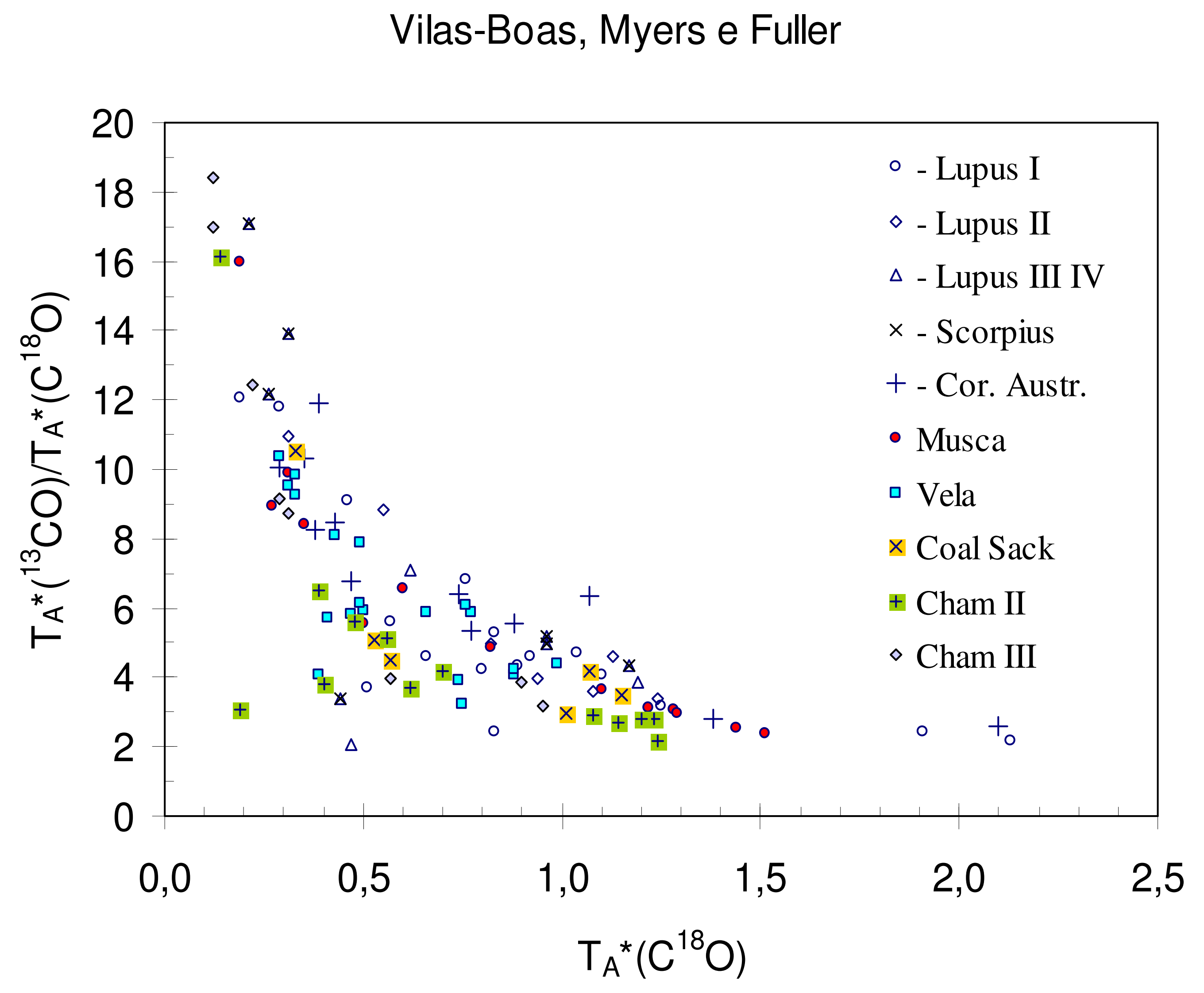


Average Values of Condensation Size, Density, and Mass

Source	L (pc)	$n(H_2)$ (10^3 cm^{-3})	M ($M_\odot$)
Vela	**0.4 (0.3)**	**6 (3)**	**30 (71)**
	0.4 (0.2)	6 (4)	24 (22)
Musca	**0.3 (0.1)**	**3 (2)**	**13 (14)**
	0.3	4.0	19
Coalsack	**0.3**	**4.5**	**18**
	0.3	5.1	20
Chamaeleon II	**0.3**	**7.0**	**22**
	0.3	8.6	27
Chamaeleon III	**0.3**	**4.0**	**12**
	0.4	5.5	12


MLB+Nozawa+TR
$T_A*(^{13}CO)/T_A*(C^{18}O)$
$T_A*(C^{18}O)$
0
4
8
12
16
20
0
1
2
3
4
- High Lat Clo
- Ophiuchus North
- Cepheus
- Ophiuchus
- Taurus
- Perseus

3 - Resultados



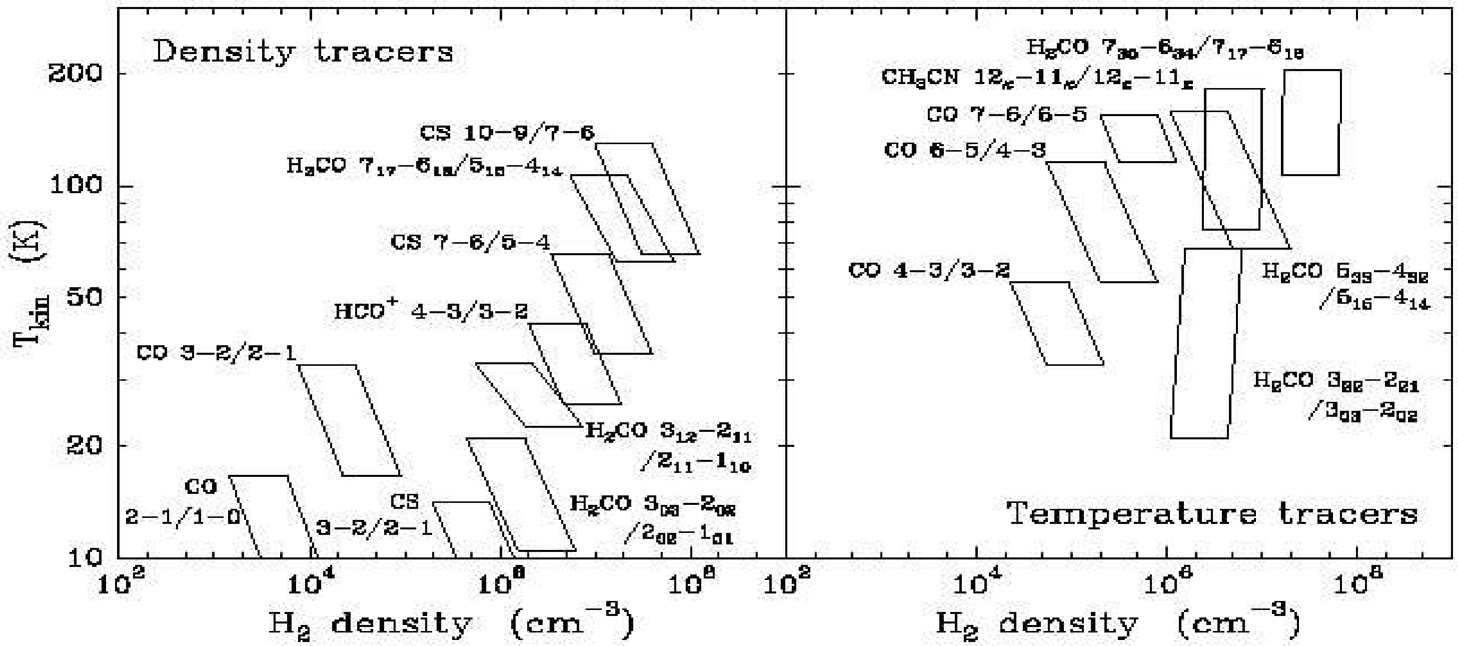


Figure: Example of molecular line ratios which are used to constrain the density and temperature structure of YSO envelops
(Van Ddishoeck, E.,F. and Hogerheijde, 1999, The origin of stars and planetary systems , p97 eds Ladda e Kylafis)