The formation of H_2S in dark clouds

Asunción Fuente
Observatorio Astronómico Nacional (OAN,IGN)

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The Hydride Toolbox, Paris 12 – 15 December 2016

Our project

To determine the ionization degree, C, N, O and S depletions as a function of Av

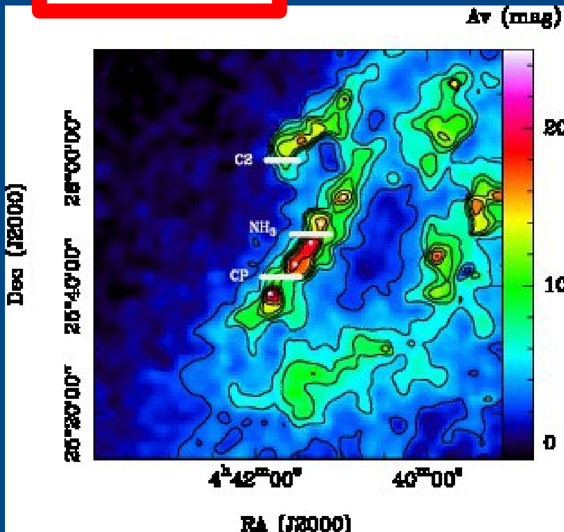
Why ?

1.- Strong implications on our understanding of the gas chemistry and the chemical composition of grains and mantles.

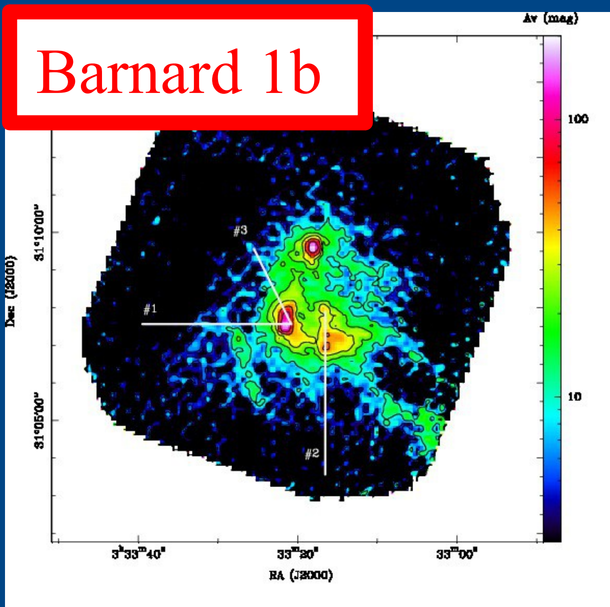
2.- The ionization degree governs the coupling of the magnetic fields with the gas.

Our sample

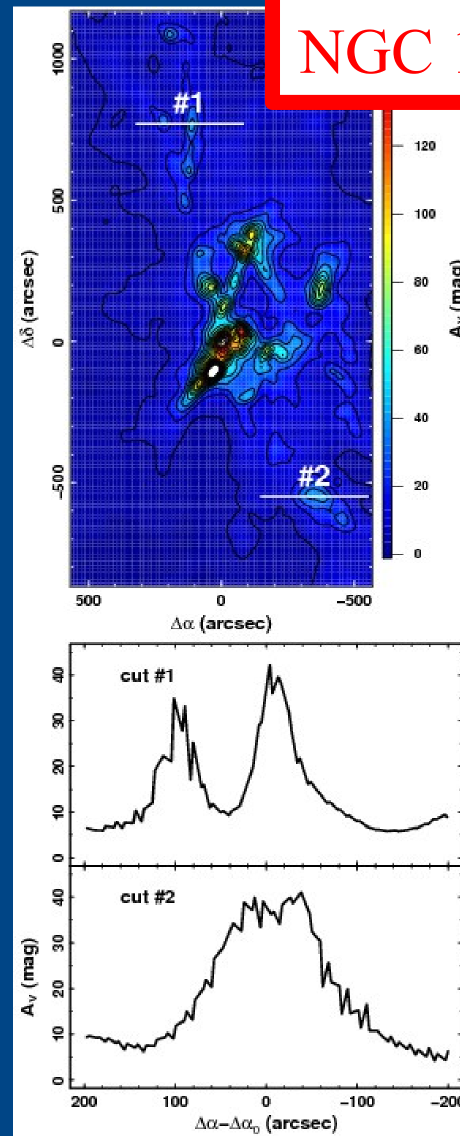
TMC1



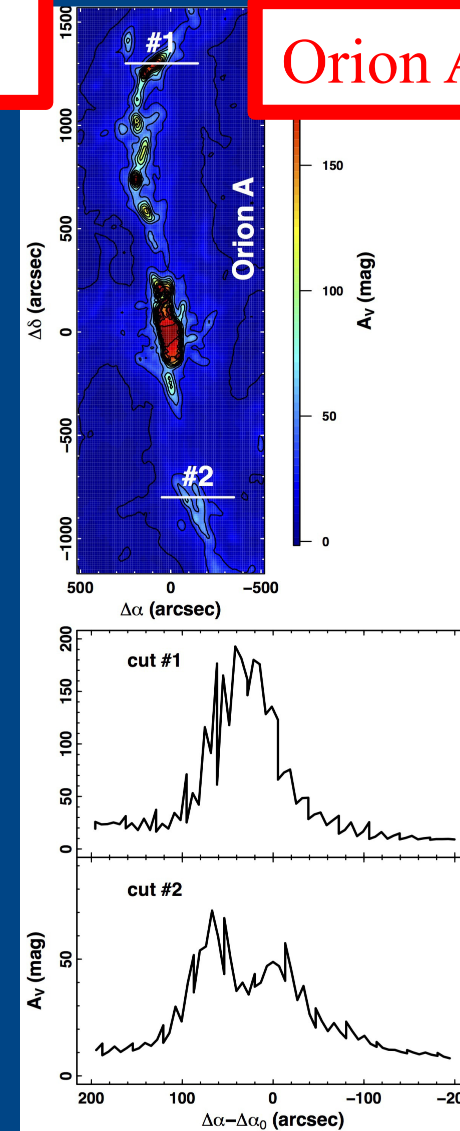
Barnard 1b



NGC 1333



Orion A



Our project

Selected species to determine the ionization fraction and elemental abundances

	$X(e^-)$	C/H	O/H	S/H	N/H	Other
^{13}CO, $C^{18}O$	X	X				
HCO^+ , $H^{13}CO^+$, $HC^{18}O^+$,	X					
HCN, $H^{13}CN$, N_2H^+	X	X			X	
CS, $C^{34}S$, ^{13}CS, SO, ^{34}SO, HCS^+	X		X	X		
OCS, H_2CS, SO_2			X	X		
NH_2D					X	X

Cloud outskirts Av < 20 mag

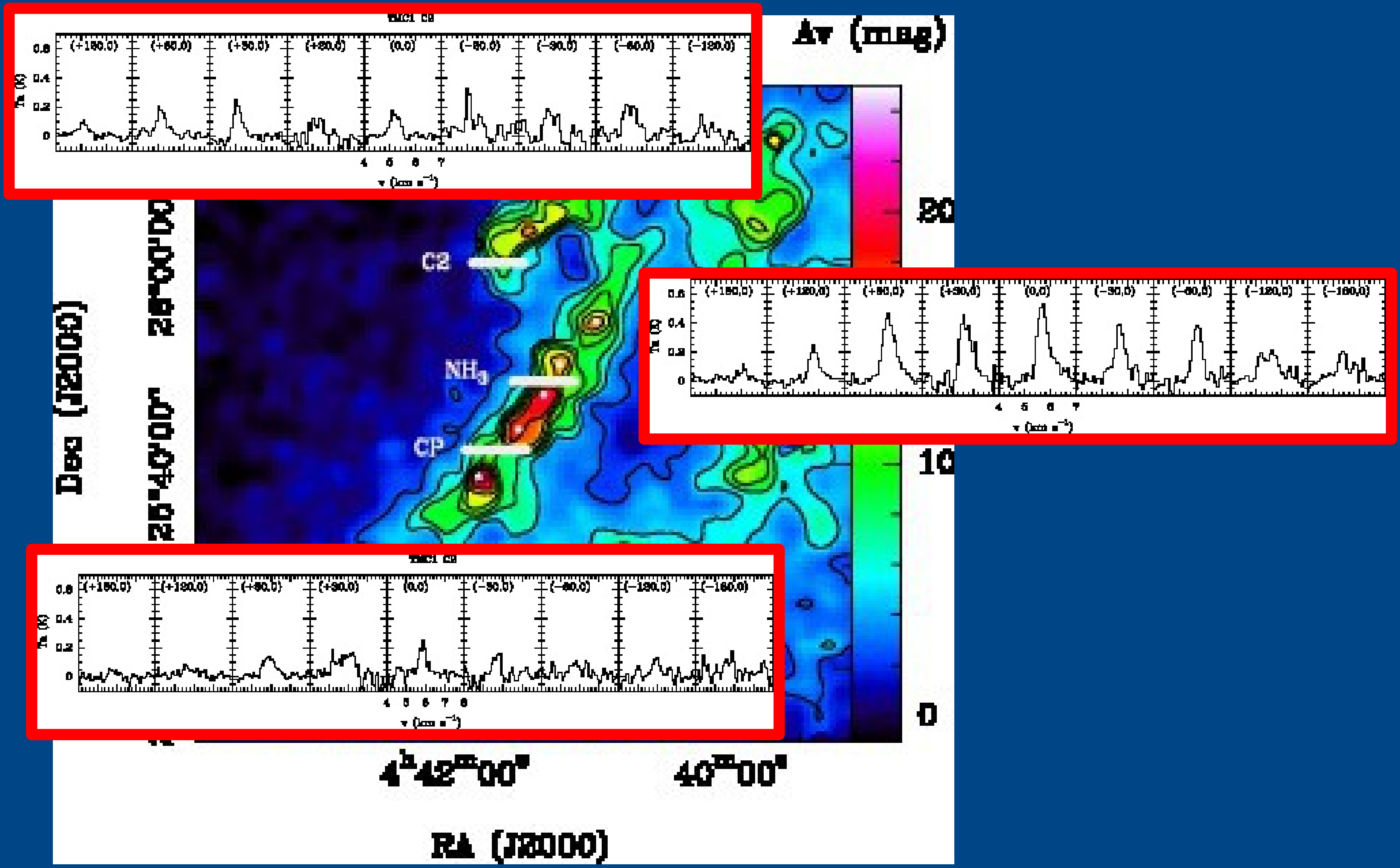
Selected transitions

Line	Quantum numbers	Freq (MHz)	E_{up} (K)	A_{ij} (s^{-1})	gu
H_2S	$1_{1,0}$ - $1_{0,1}$	168762.75	8.1	2.677E-05	3
SO	2_3 - 1_2	99299.89	9.2	1.125E-05	7
CS	2 - 1	97980.95	7.1	1.679E-05	5

110 positions

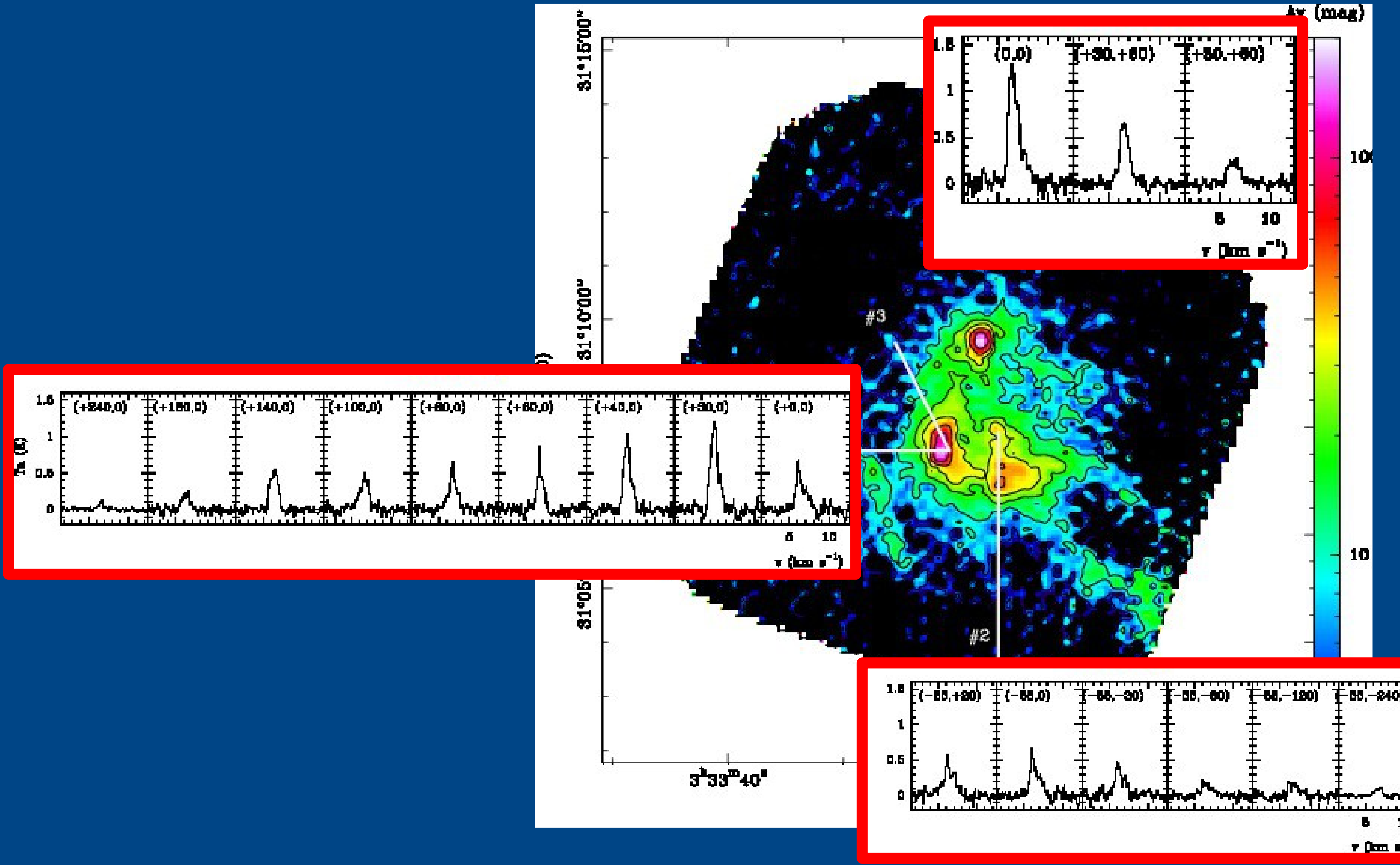
- 45 in TMC1
- 20 in Barnard 1b
- 30 in NGC 1333
- 15 in Orion A

H_2S in TMC1

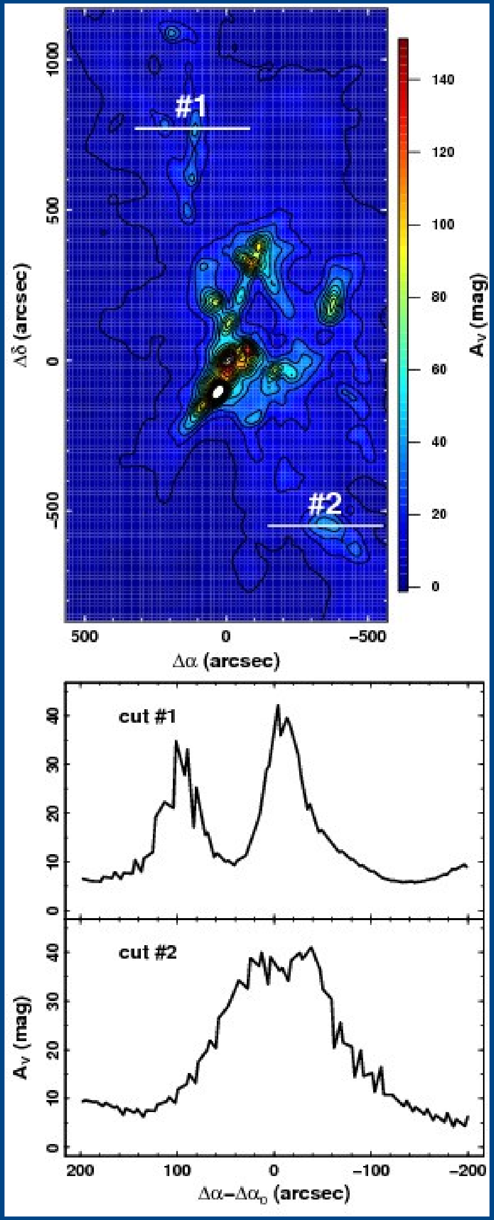


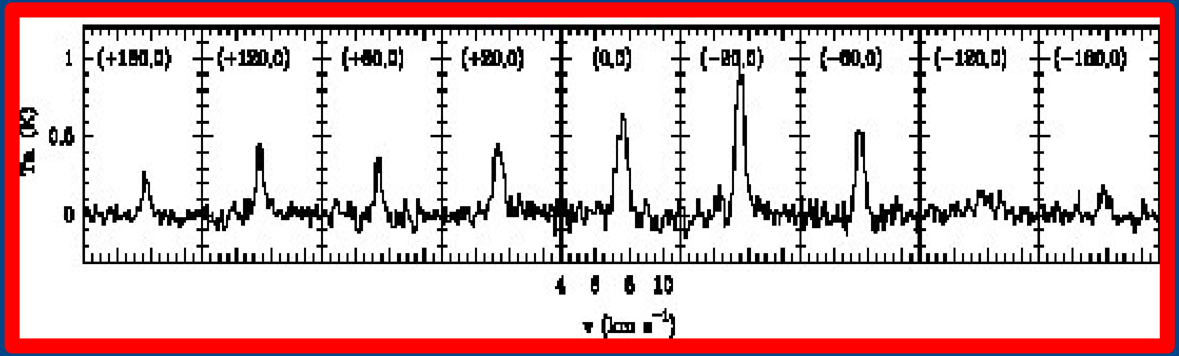
Av (mag)
20
10
0
C2
NH3
CP
Dec (J2000)
25°40'00"
25°50'00"
RA (J2000)
4h42m00s
40m00s
TMC1 C2
TMC1 CP
v (km s⁻¹)

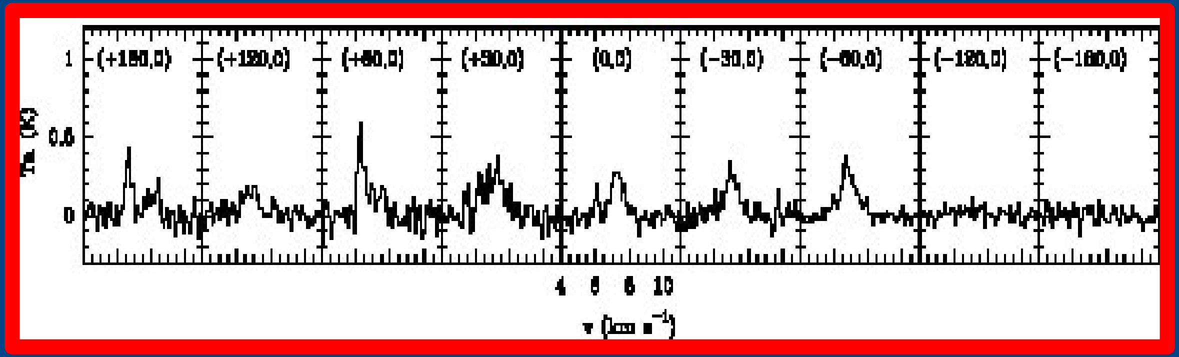
H_2S in Barnard 1b



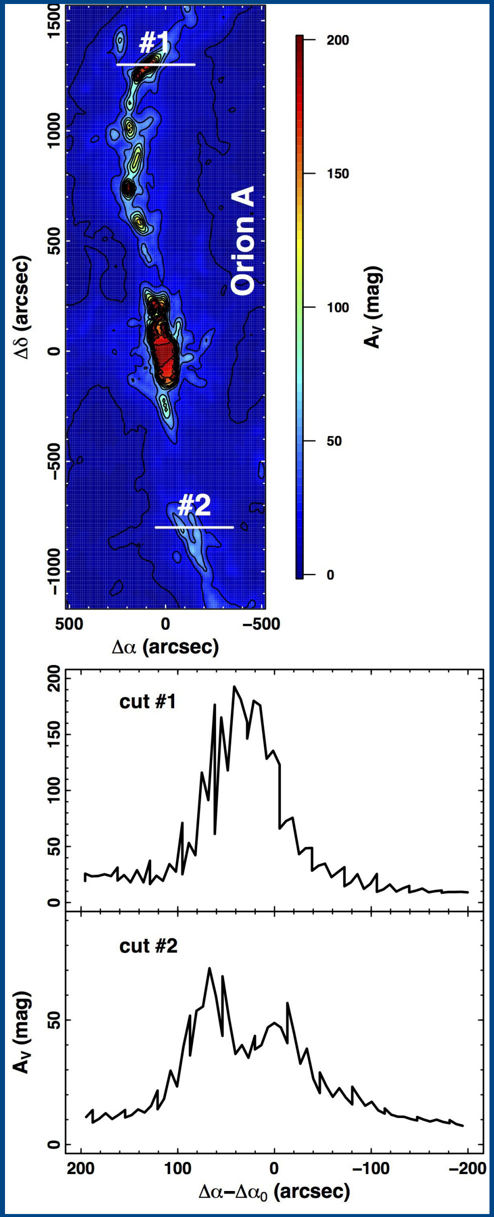
H_2S in NGC 1333

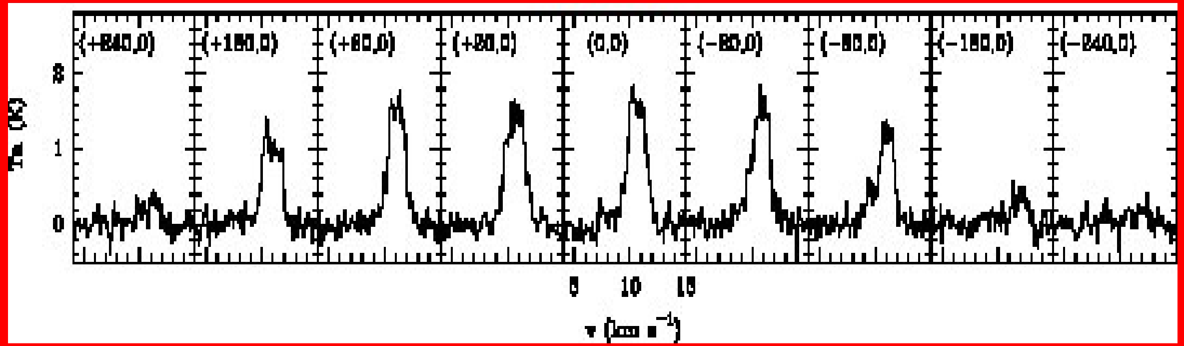




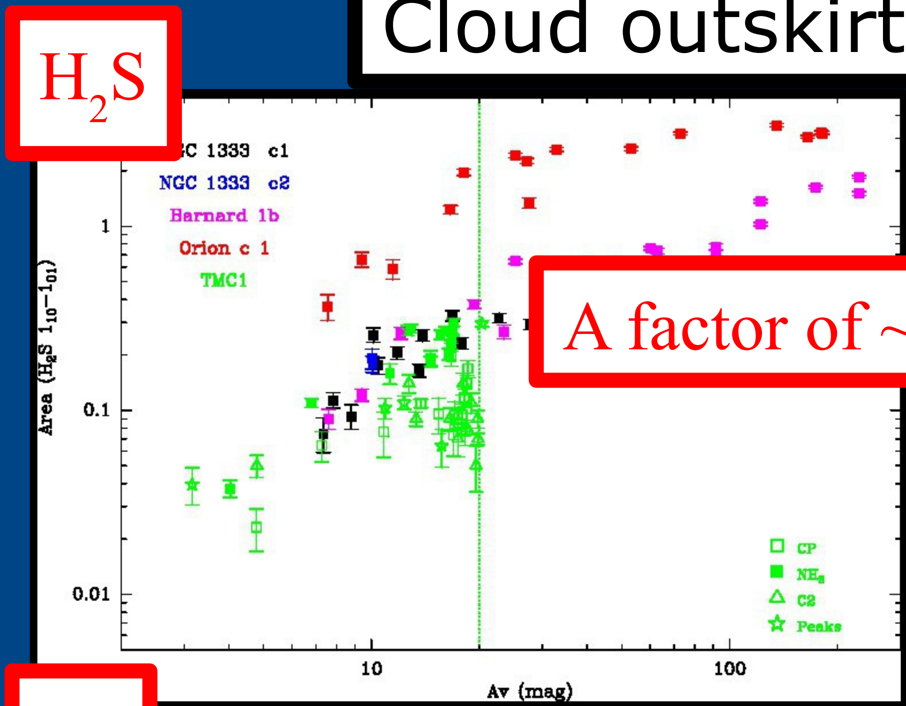


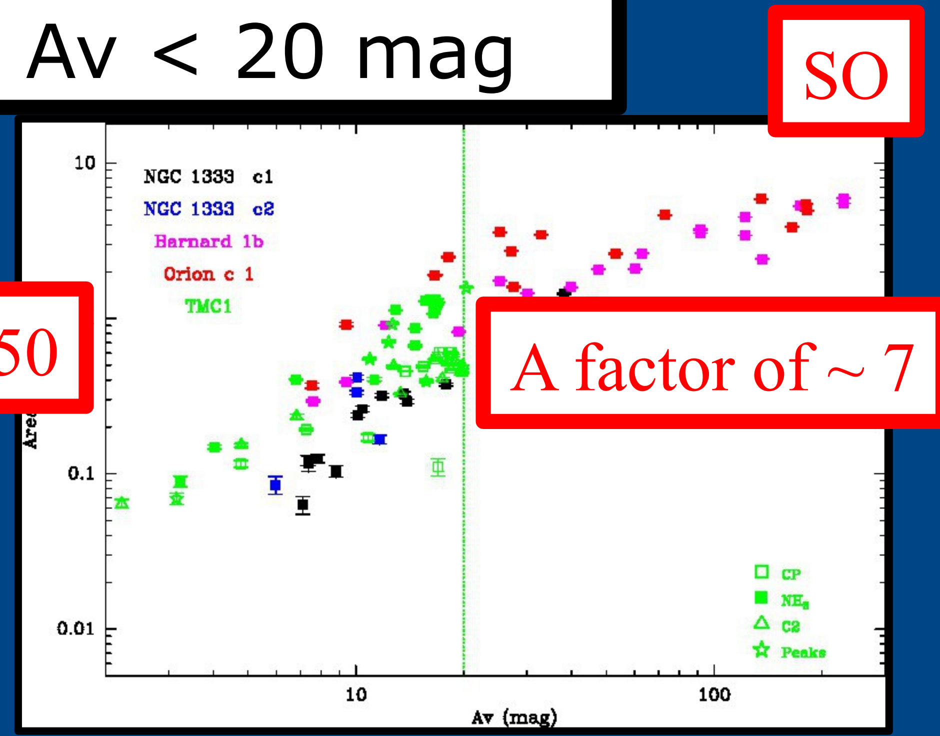
H_2S in Orion A

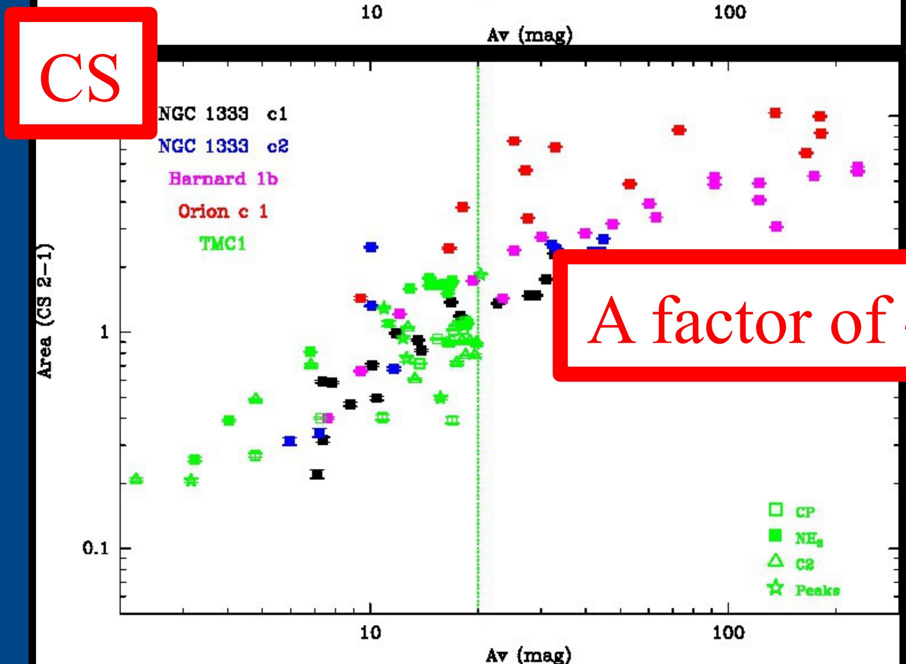




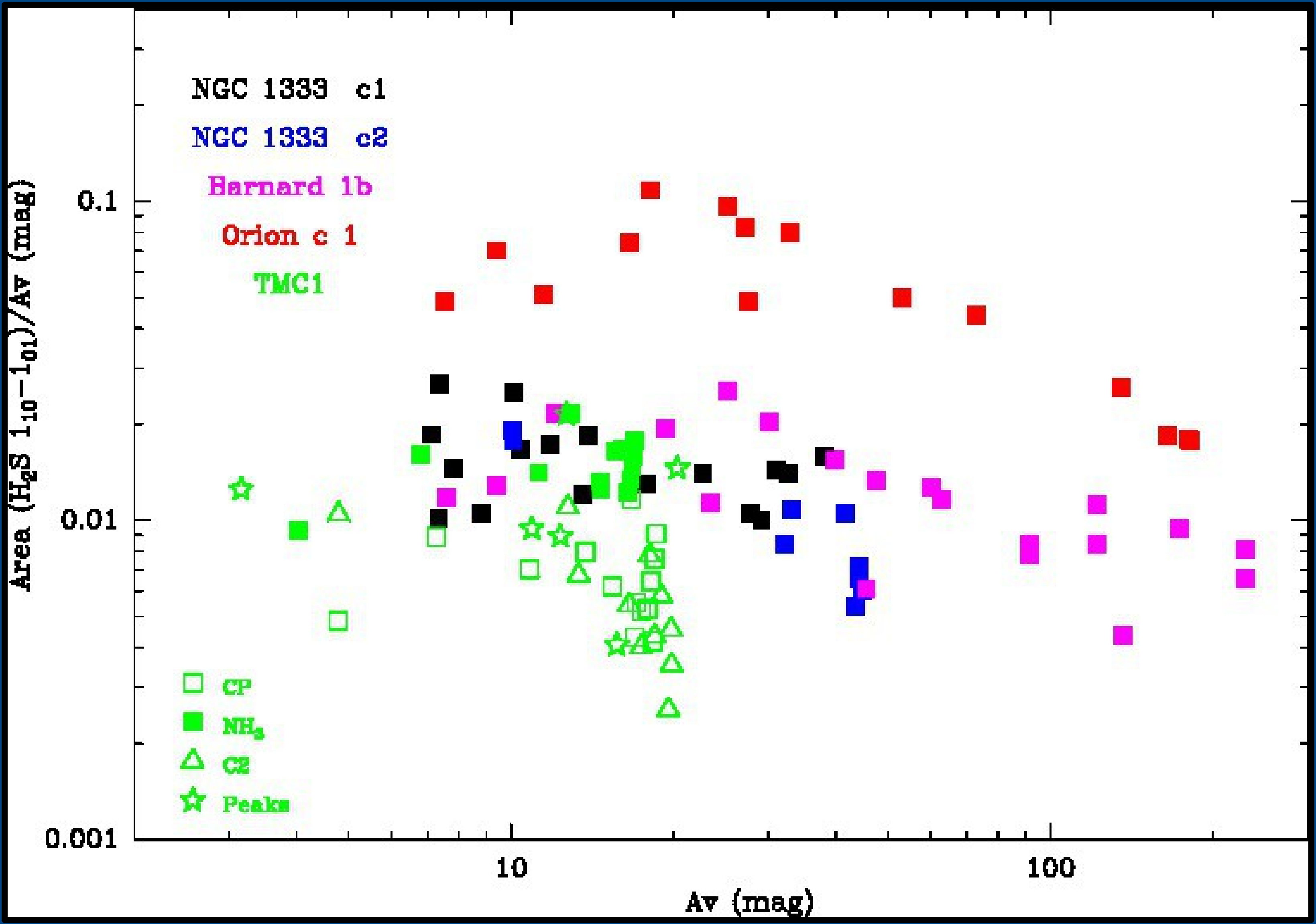
Cloud outskirts Av < 20 mag





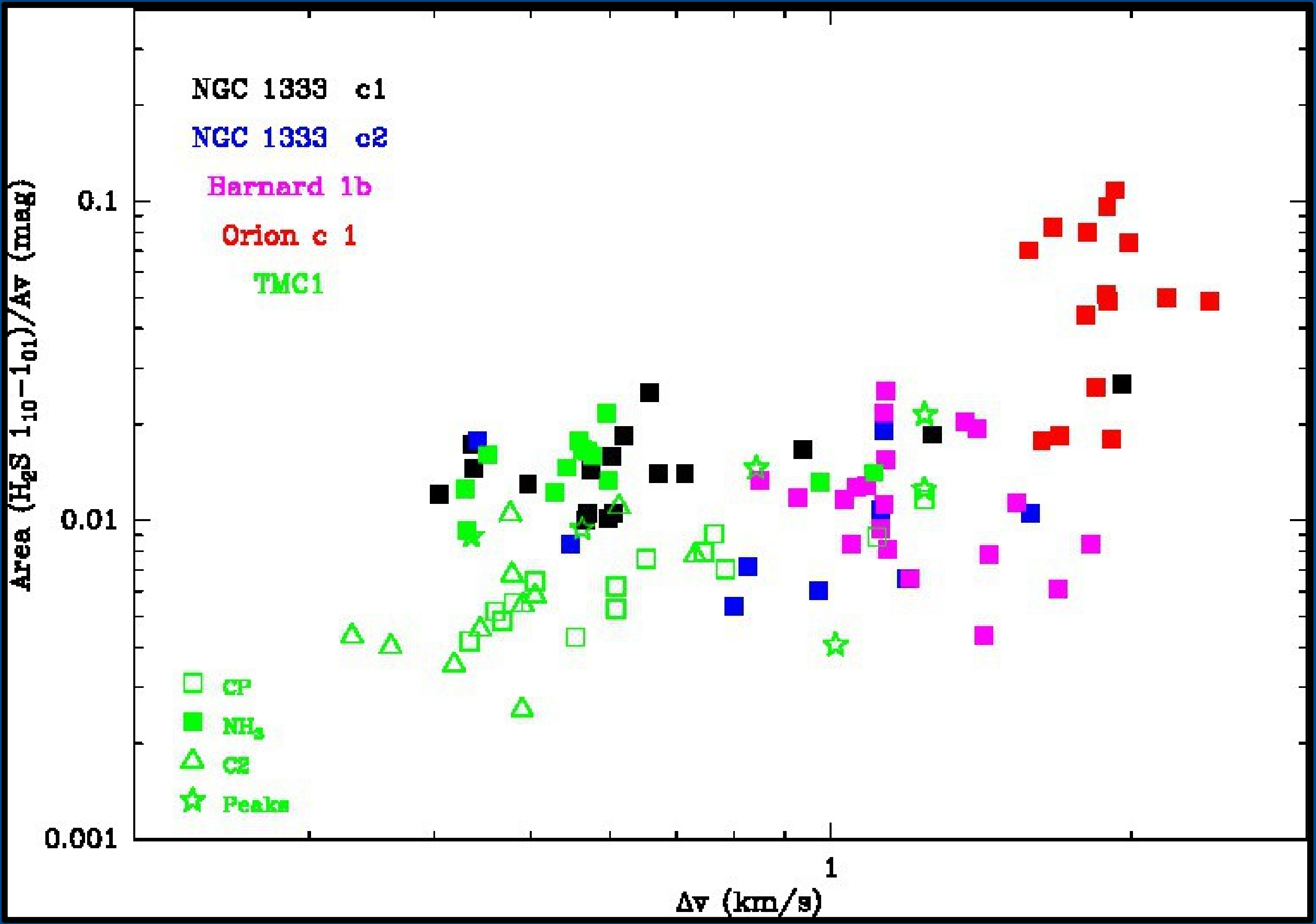


$X(H_2S)$ vs Av

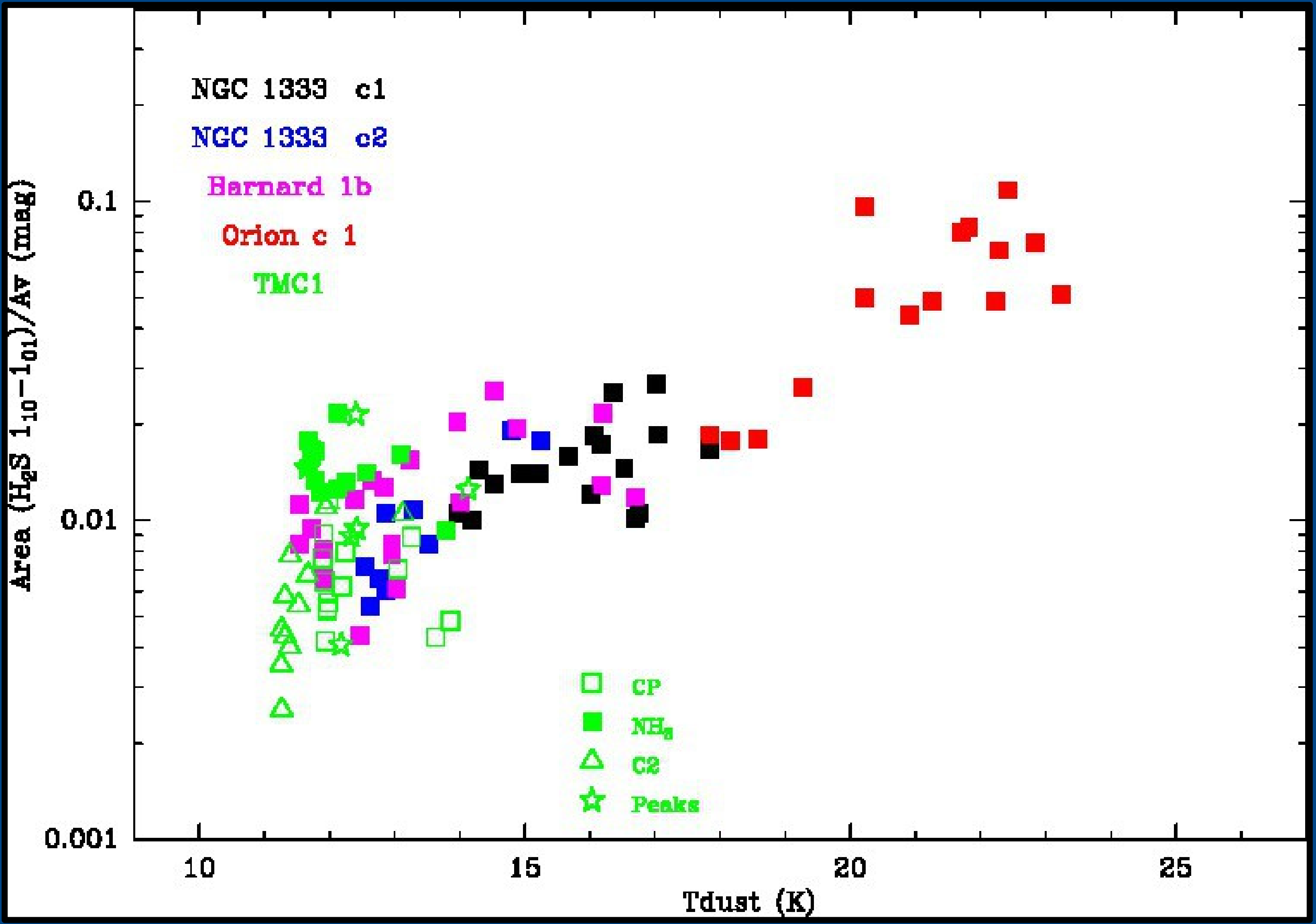


NGC 1333 c1
NGC 1333 c2
Barnard 1b
Orion c 1
TMC1
CP
NH3
C2
Peaks
0.1
0.01
0.001
10
100
Av (mag)
Area (H2S 110−101)/Av (mag)

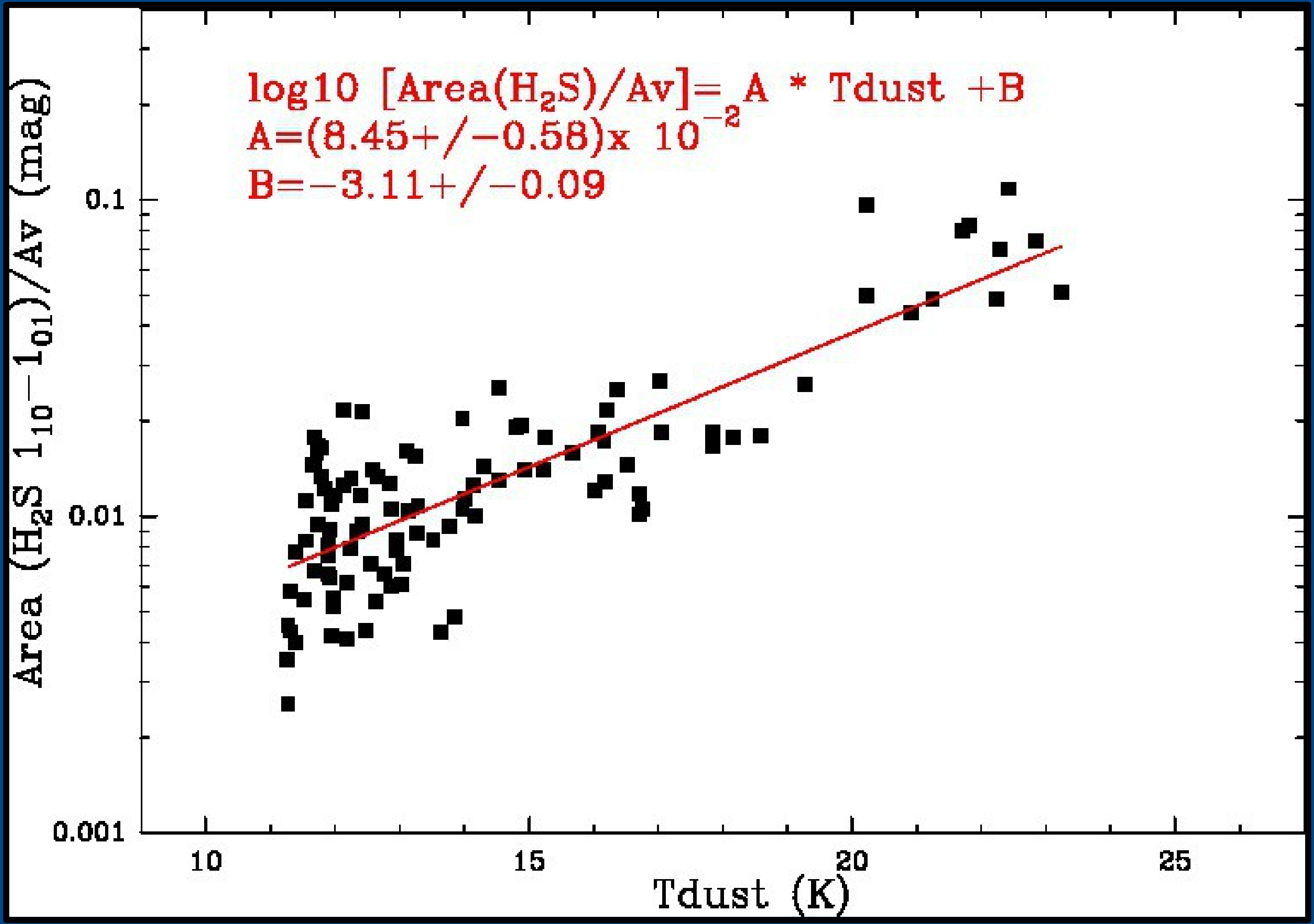
$X(H_2S)$ vs Δv



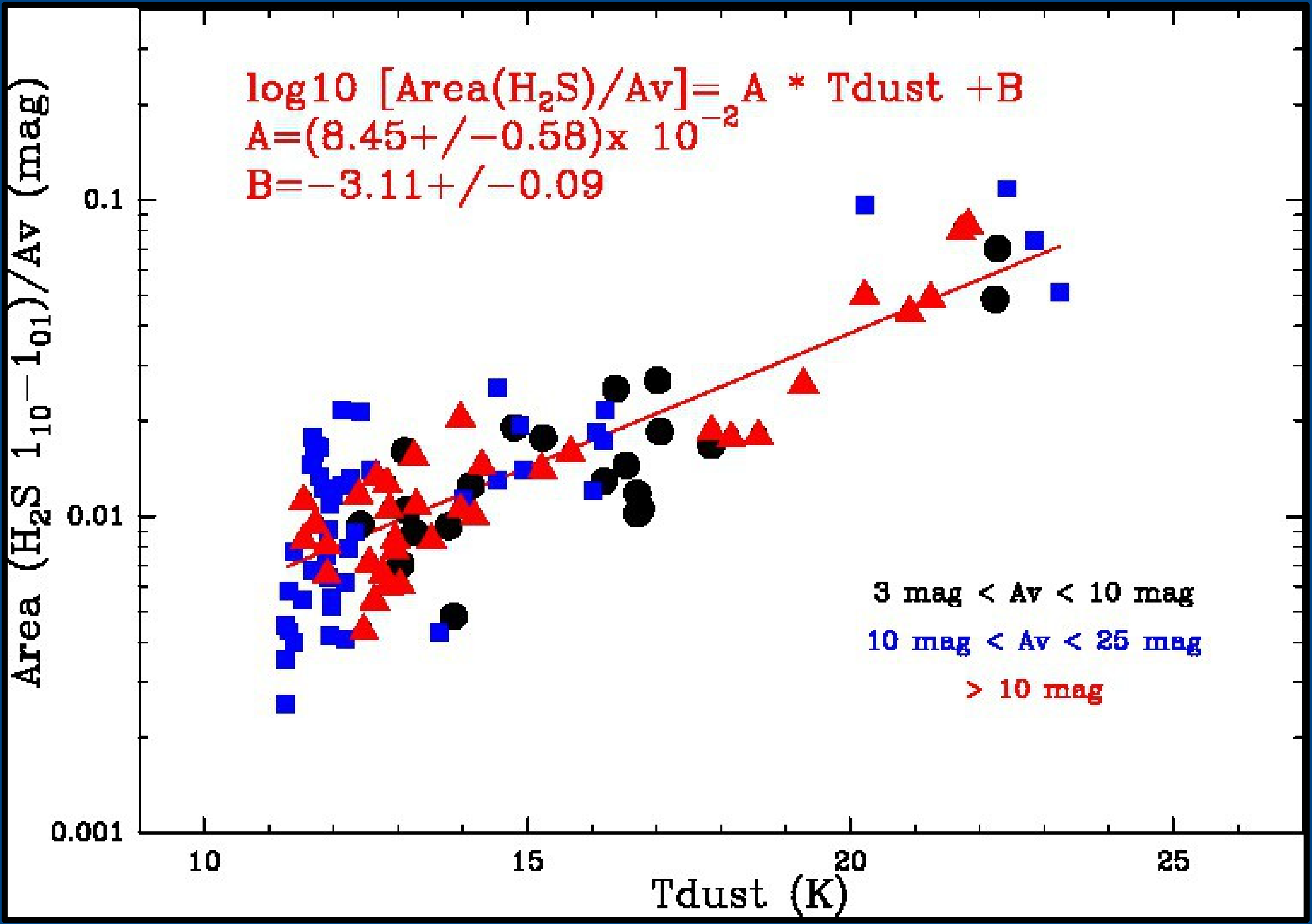
$X(H_2S)$ vs Tdust



X(H_2S) vs Tdust



$X(H_2S)$ vs Tdust



H_2S abundance

$$\log 10[X(H_2S)] = 8.45E\text{-}2\ T_{dust} - 10.83$$

$X(H_2S) \approx 10^{-10}$ for T_{dust}=10 K

$X(H_2S) \approx 10^{-8}$ for T_{dust}=30 K

H_2S formation

Thermal desorption Tdust > 70 K

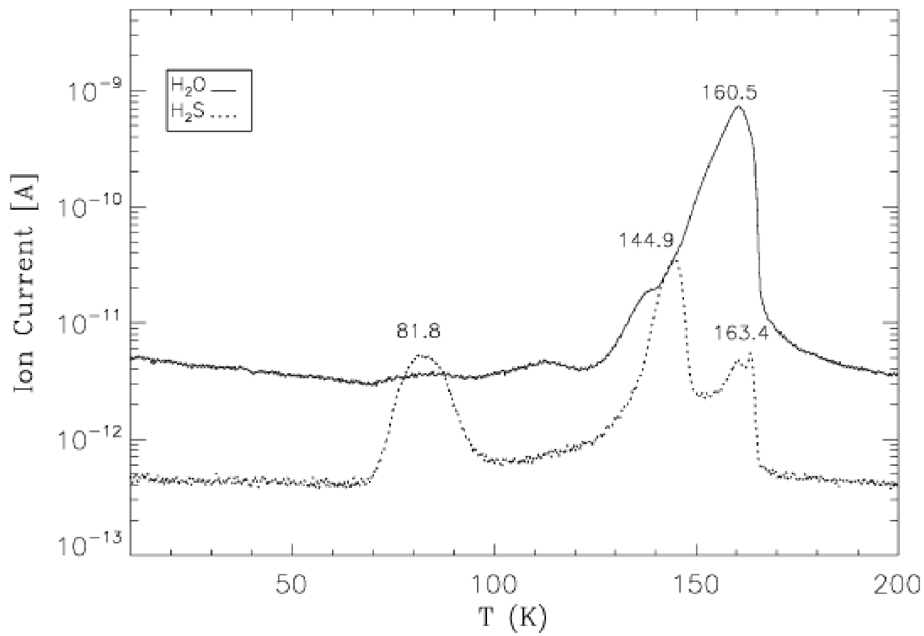


Fig. 4. Thermal desorption of the H_2S:H_2O = 7.5:100 ice mixture, with a heating rate of 1 K min^{-1}, corresponding to experiment S6 of Table 1. The ion current in Ampere, represented on the y-scale, corresponds roughly to the partial pressure in mbar.

Jiménez-Escobar & Muñoz-Caro 2011, A&A 536, 91

H_2S formation

Photodesorption: Dependence with dust temperature

In a PDR, dust temperature is related to the incident UV field, G_0

$$T_d = \{8.9 \times 10^{-11} \nu_0 G_0 e^{-1.8 A_v} + 2.7^5 + 3.4 \times 10^{-2}[0.42 - \ln(3.5 \times 10^{-2} \tau_{100} T_0)] \times \tau_{100} T_0^6\}^{0.2} ,$$

$$T_0 = 12.2 G_0^{0.2} \text{ K}$$

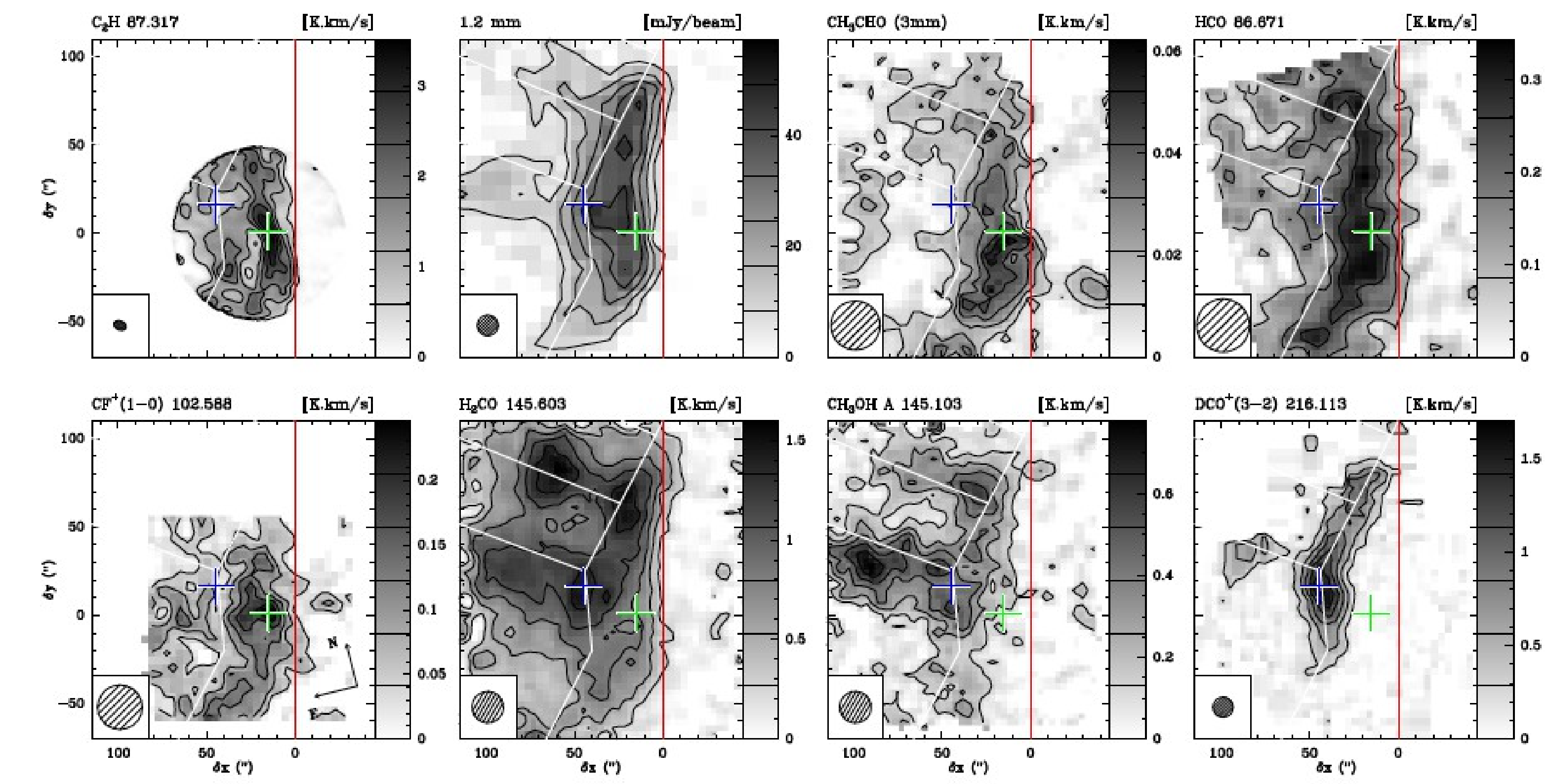
(Hollenbach, Takashi & Tielens, 1991, ApJ 377 192)

H_2S formation

Photodesorption: Dependence with dust temperature

The photodesorption rate can depend on the dust temperature. This effect has been recently measured in CO and H_2O (Öberg et al. 2009, A&A 496, 281 and ApJ 663, 1209; Muñoz-Caro et al. 2016, A&A 589, 16)

A proto-typical PDR: The Horsehead

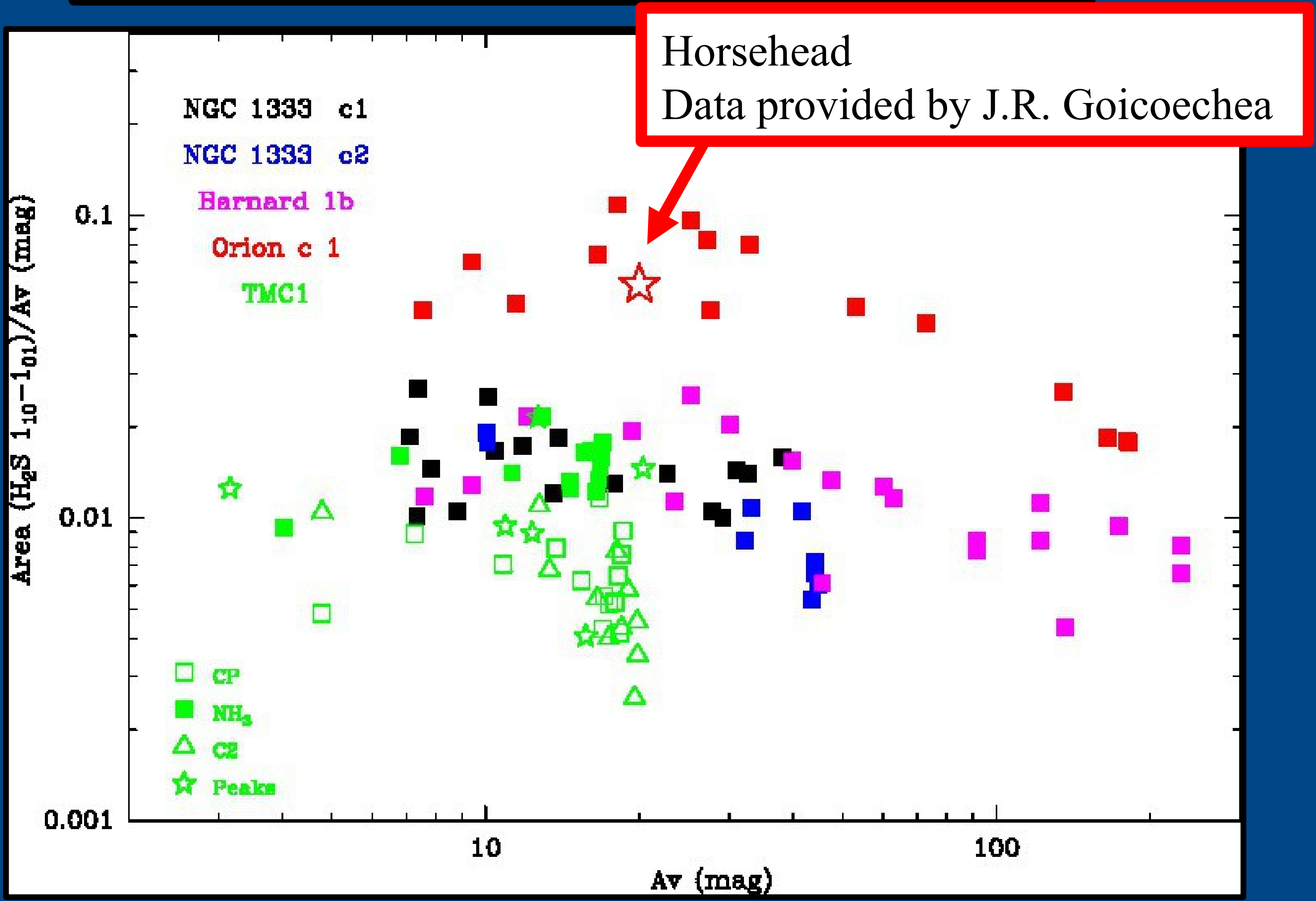


(Guzmán et al. 2014, FaDi 168, 103)

G_0=50-100

Tdust=20 -30 K

A proto-typical PDR: The Horsehead



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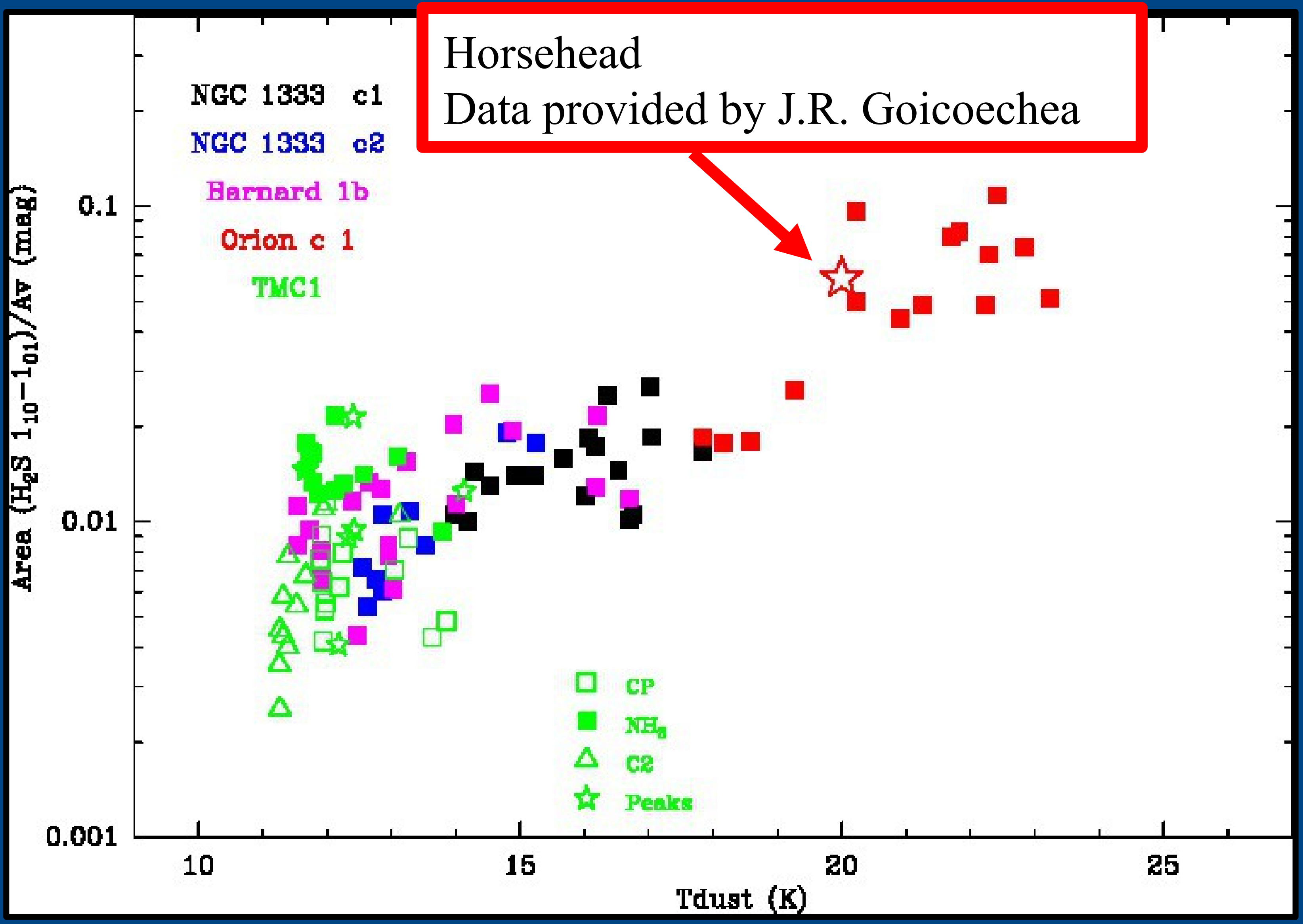

Summarizing...

1.- We have carried out a survey of H_2S in the outskirts of four molcular clouds (TMC1, Barnard 1b, NGC 1333, Orion A)

2.- The H_2S abundance is very dependent on the environment with a variation of a factor of ~50 from TMC1 to Orion A.

3.- The H_2S abundance is well correlated with the dust temperature.

4.- This dependence is explained by differente G_0 and a possible temperature dependency of the photodesorption rate.