CENTRO DE ASTROBIOLOGÍA

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Spectral line surveys of the active galaxies NGC 253, NGC 4945 and ARP 220

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Outline

1 Introduction

2 Observations and Spectral Results
- NGC 253, NGC 4945 and ARP 220 Spectra

3 Reduction, analisys and Results
- Molecules
- Parameters obtained
- Molecular Overlaping
- Tracers in the survey
- Non LTE molecule
- Abundances Comparison

4 Conclusions

Introduction

The use of surveys help us to know more about the source because the molecular emission show unique information.

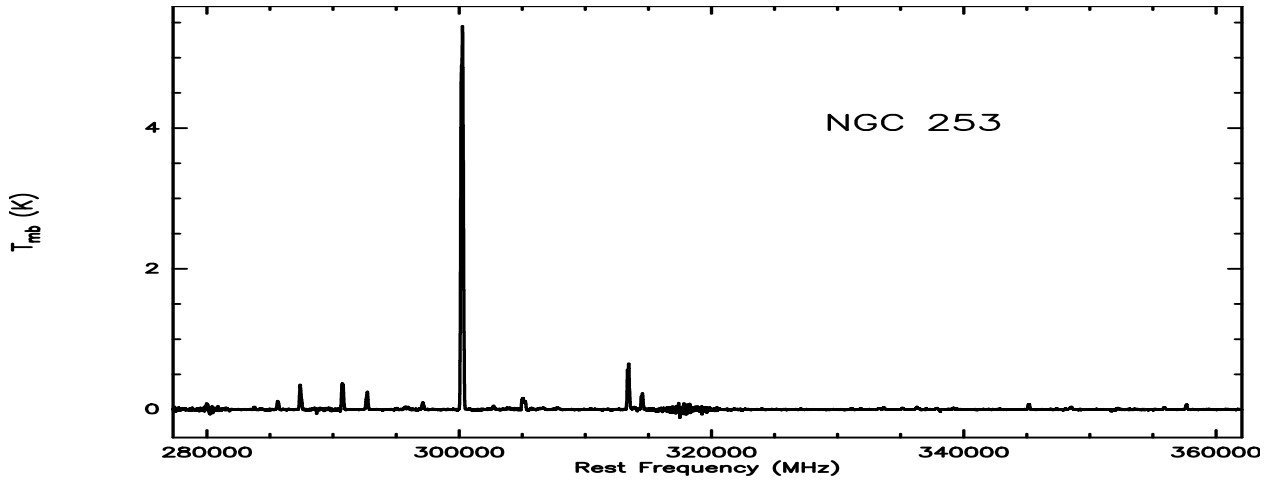
- S. Martin, et al. (2004,2006), Studied A 2mm and 3mm spectral line survey of the starburst galaxy NGC 253.
- Aladro R., et al.(2010), compared a 1.3mm and 2mm molecular line survey in M82 and NGC 253.
- S. Martin et al. (2010) studied the Submillimeter Array 1.3mm line survey of Arp 220.
- Requena M.(2012), Riquelme D. (2012) , Pintado et al. (2012) studied Galactic center region at 3mm and other frequencies.
- Wang M., et al. (2004), studied The nuclear starburst environment in NGC 4945 at 3mm and 2mm.

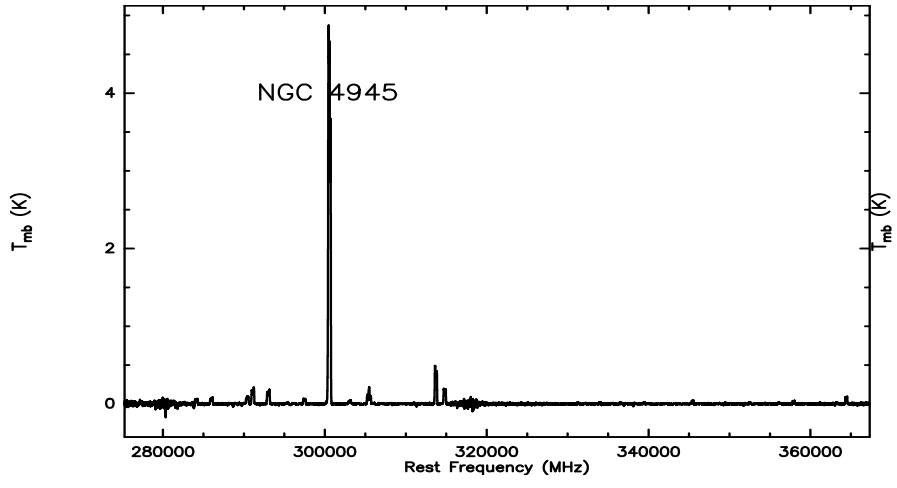
Observation

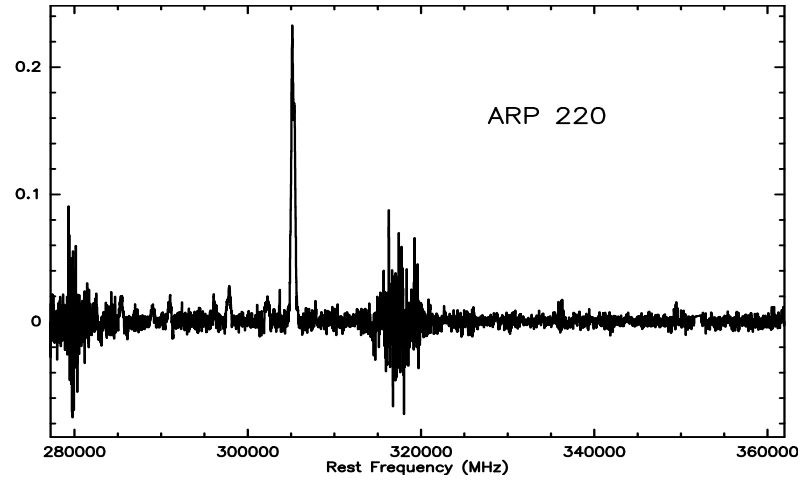
The data for the extragalactic surveys in starburst NGC253, NGC4945, and ULIRG ARP220 were obtained with the APEX 12m (Atacama Pathfinder Experiment-ALMA). We assume a limit of 1 mm of water vapor when the source was at high elevation. The new version of the 345 band in the FLASH receiver (Heyminck et al. 2006) was used.

- NGC 253: Sy2, RA= 00 47 33.134, DEC= -25 17 19.68, z=0.000814, Sculptor constelation, 3,94 Mpc.
- NGC 4945: Sy2,RA= 13 05 27.279, DEC = -49 28 04.44, z=0.001908, Centaurus Constelation.
- ARP 220: ULIRG, RA= 15 34 57.272, DEC= +23 30 10.48, z=0.018116, Serpens Constelation, 77Mpc.

NGC 253, NGC 4945 and ARP 220 Spectra







Reduction and analisys

- Class: Data was initially reduce and calibrated using GILDAS/CLASS software with the main-beam efficiency at the frequency of this line being 0.67.
- MADCUBA: We used MADCUBAIJ to identify molecular lines and fit gauss line profiles to the spectra of CO and its isotopologues. Based on the fitted parameters we calculated column density for CO and isotopologues using the MADCUBAIJ LTE analysis.

The source size was taken from Martin el al. 2006 . We used size of 20 sec for NGC 4945 and NGC 253, while 2 sec for ARP 220. The source brightness temperature (TB) can be estimated from the measured main beam brightness temperature as

$$\mathrm{TB} = \eta_{bf}^{-1}\,\mathrm{TMB}$$

where, size θs observed with a Gaussian beam of size θb, the beam filling factor is

$$\eta_{bf} = \theta_s^{-2}/(\theta_s^{-2} + \theta_b^{-2})$$

Molecules

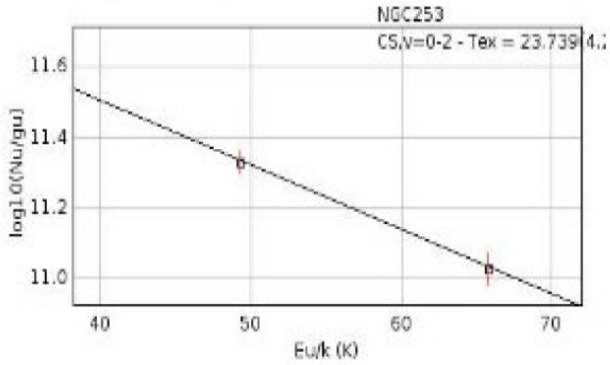
We identified and analyzed molecular lines from the survey, we found 11 molecular lines for ARP 220, 15 for NGC 4945 and 25 for NGC 253. Detected molecules in the APEX surveys: List of the molecules that have been observed in external galaxies are shown.

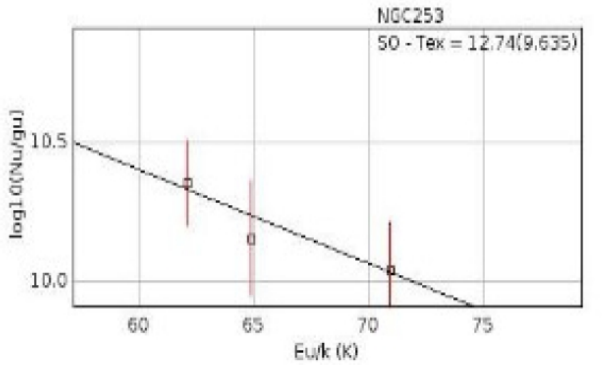
Molecules	Galaxy	Molecules	Galaxy
CO	ARP 220, NGC 4945, NGC 253	H2CO	NGC 4945, NGC 253
HCN	ARP 220, NGC 4945, NGC 253	SO	NGC 4945, NGC 253
CCH	ARP 220, NGC 4945, NGC 253	C3H2	NGC 4945
CS	ARP 220, NGC 4945, NGC 253	N2H+	NGC 4945, NGC 253
HCO+	ARP 220, NGC 4945, NGC 253	CS-34	NGC 253
HNC	ARP 220, NGC 4945, NGC 253	HNCO	NGC 253
CH3OH	ARP 220, NGC 4945, NGC 253	CH2NH	NGC 253
H3O+	ARP 220, NGC 4945, NGC 253	CH3CCH	NGC 253
OCS	ARP 220, NGC 253	H2CS	NGC 253
H2S	ARP 220, NGC 253	NH2CN	NGC 253
CN	ARP 220, NGC 253	SiO	NGC 253
CO-18	NGC 4945, NGC 253	NO	NGC 253
CO-17	NGC 4945, NGC253		
C-13-O	NGC 4945, NGC253		

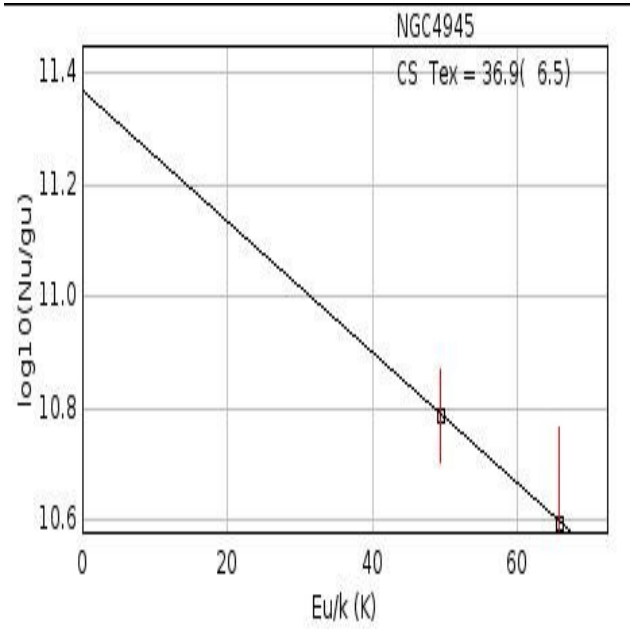
Rotational Diagrams

The population distribution can be fitted by a straight line (formed by points of each transition)that provides the total column density divided by the partition function as well as Trot.
For the galaxy NGC 253 we obtained rotational diagram for CS and SO, we found from 15-24 K for the rotational Temperature. .
We find the rotational Diagram for NGC 4945, we used CS and found a rotational temperature from 31-48 K.

In order to find the rotational temperature of ARP 220 we used 15 K from literature (Martin et al. 2010).







Parameters obtained for NGC 4945

We have 3 components for NGC 4945 but in the table we shown an average, the fit of the molecules was based in the fit for HCN because is the most clear, exception HNC.

Molecules	N (cm^{-2})	Tex (K)	Abundance [X]/[H2]
CO	1.31^{18}	38.72	2.04^{-5}
HCN	6.61^{13}	38.72	1.03^{-9}
CCH	3.97^{14}	38.72	6.2^{-9}
CS	8.19^{13}	38.72	1.28^{-9}
HCO+	4.44^{13}	38.72	6.94^{-10}
HNC	5.39^{13}	15.22	8.43^{-10}
CH3OH	2.59^{14}	38.72	4.05^{-9}
H3O+	2.11^{14}	38.72	3.30^{-9}
CO-18	5.04^{16}	38.72	7.88^{-7}
CO-17	1.9^{15}	38.72	2.97^{-8}
C-13-O	1.24^{17}	38.72	1.93^{-6}
H2CO	3.86^{13}	38.72	6.03^{-10}
SO	3.88^{13}	38.72	6.07^{-10}
C3H2	5.67^{12}	38.72	8.8^{-11}
N2H+	1.51^{13}	38.72	2.36^{-10}

Parameters obtained for NGC 253

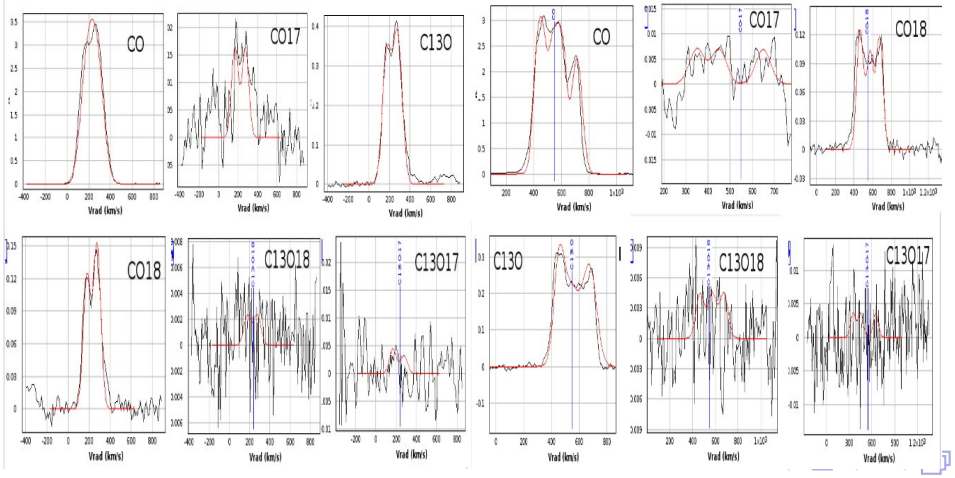
We have 2 components for NGC 253 but in the table we shown an average.

Molecules	N (cm^{-2})	Tex (K)	Abundance [X]/[H2]
CO	1.78^{18}	19.98	2.66^{-5}
HCN	1.02^{14}	19.98	1.53^{-9}
CCH	4.17^{14}	19.98	6.23^{-9}
CS	1.93^{14}	19,15	2.89^{-9}
HCO+	8.18^{13}	19.98	1.31^{-9}
HNC	3.23^{13}	19.98	4.83^{-10}
CH3OH	3.47^{14}	19.98	5.18^{-9}
H3O+	2.57^{14}	19.98	3.84^{-9}
CO-18	4.68^{16}	19.98	6.99^{-7}
CO-17	6.07^{15}	19,15	9.05^{-8}
C-13-O	1.39^{17}	19.98	2.08^{-6}
H2CO	4.9^{13}	19.98	7.33^{-10}
SO	1.85^{14}	19.98	2.77^{-9}
N2H+	1.83^{13}	19.98	2.74^{-10}
CS-34	1.85^{13}	19,15	2.76^{-10}
HNCO	1.22^{15}	19.98	1.83^{-8}
CH2NH	5.67^{13}	19.98	8.46^{-10}
CH3CCH	2.79^{16}	20	4.16^{-7}
H2CS	2.09^{13}	19.98	3.12^{-10}
NH2CN	1.02^{14}	19.98	1.52^{-9}
SiO	1.10^{13}	19.98	1.64^{-10}
NO	4.97^{15}	19.98	7.42^{-8}

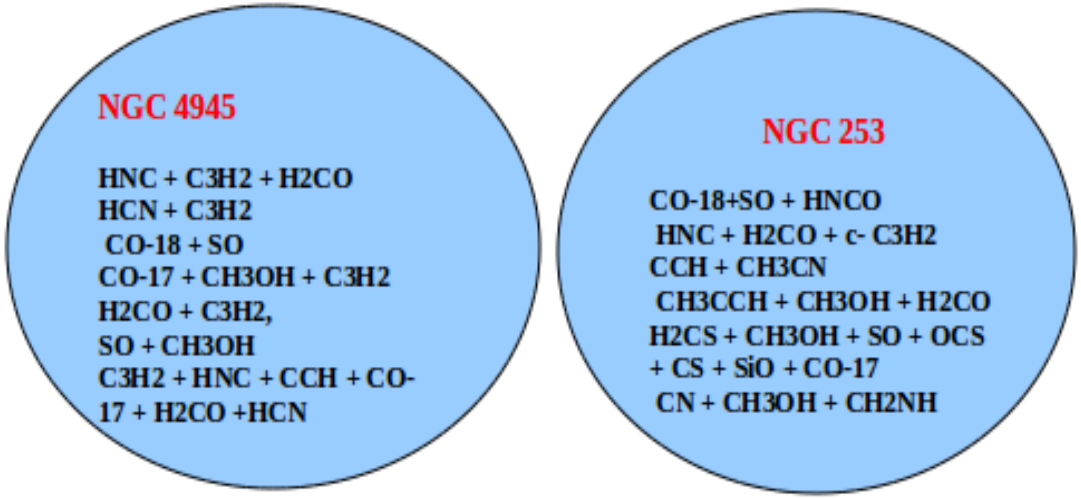
Parameters obtained for ARP 220

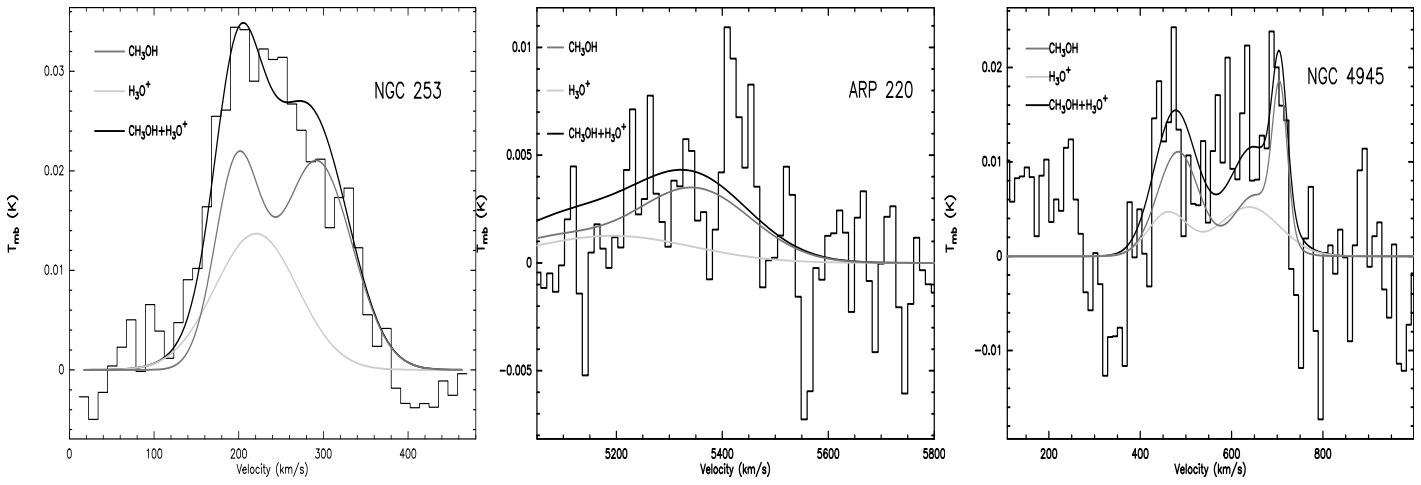
We shown the obtained parameters, we have 2 components for ARP 220, but the amount indicated in the table are average of parameters.

Molecules	N (cm^{-2})	Tex (K)	Abundance [X]/[H2]
CO	1.15^{18}	15	$1{,}72^{-5}$
HCN	1.21^{15}	15	1.81^{-8}
CCH	1.53^{16}	15	2.28^{-7}
CS	3.22^{15}	15	4.81^{-8}
HCO+	3.79^{14}	15	5.66^{-9}
HNC	7.29^{14}	15	1.08^{-8}
CH3OH	6.15^{15}	20	9.18^{-8}
H3O+	3.81^{15}	20	5.68^{-8}
OCS	1^{16}	15	2.98^{-7}
H2S	6.25^{18}	15	9.34^{-5}
CN	8.9^{14}	15	1.33^{-8}

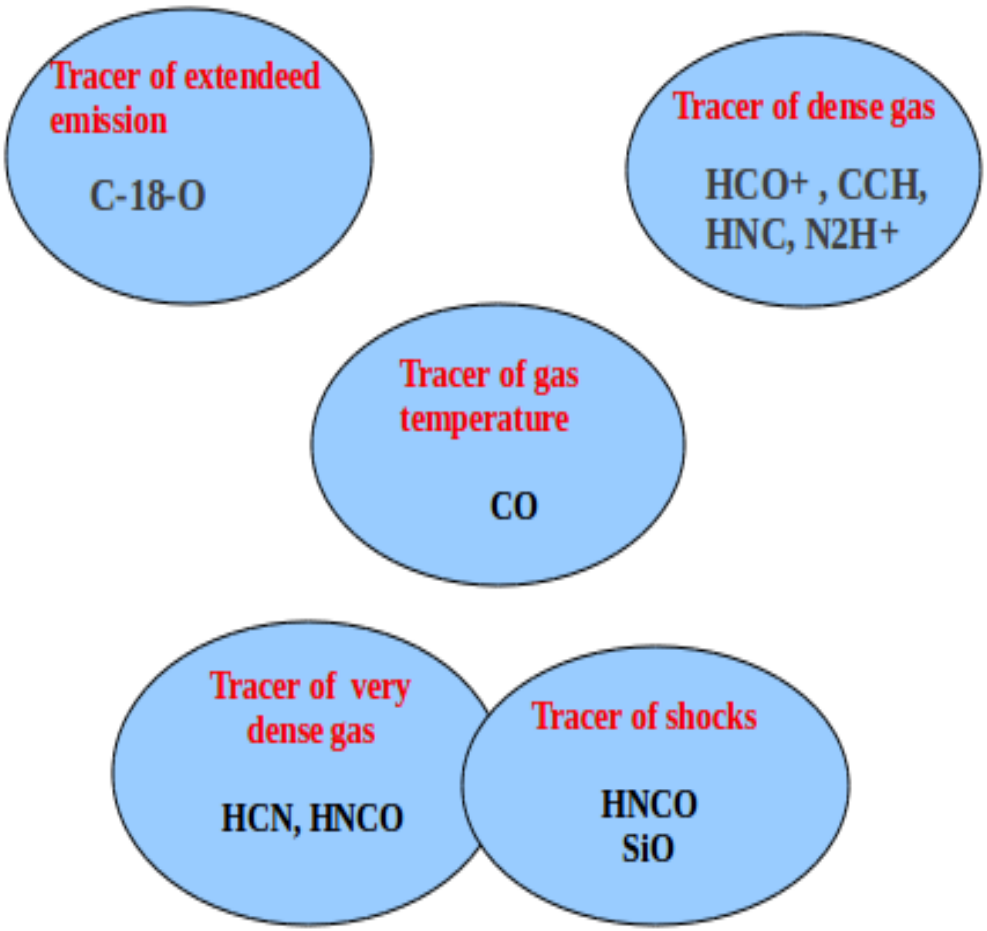


Molecular Overlaping



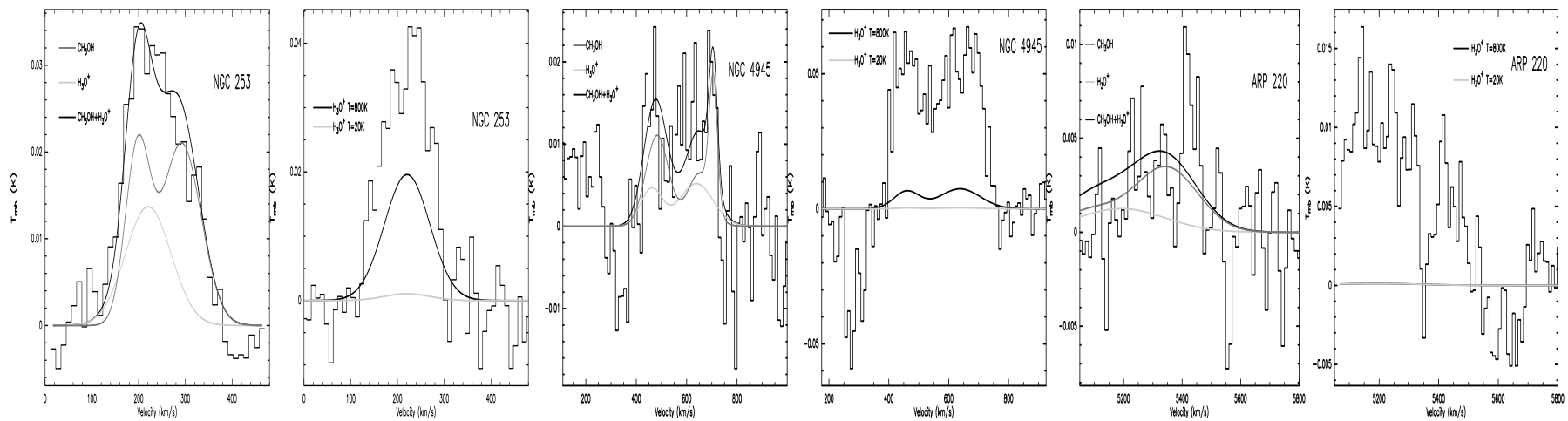


Tracers


Tracer of extendeed emission
C-18-O
Tracer of dense gas
HCO+ , CCH, HNC, N2H+
Tracer of gas temperature
CO
Tracer of very dense gas
HCN, HNCO
Tracer of shocks
HNCO
SiO

Non LTE molecule

We fitted parameters using the MADCUBAIJ LTE analysis. We can not use LTE to fit H_3O^+ , at ν= 364.7974 GHz the temperature was higher than at ν= 307.1924 GHz for H_3O^+, that mean ν= 364.7974 GHz line is overpopulated. There are two possibilities to explain our results: Radiative pumping or exitence of Maser.
ILHUIYOLITZIN V.P. et al. (2013), The anormal case of H3O+ in NGC 253, NGC 4945 and ARP 220 galaxies, Astronomy and Astrophysics, in prep.
we show it in the figures of the spectra for the three galaxies.



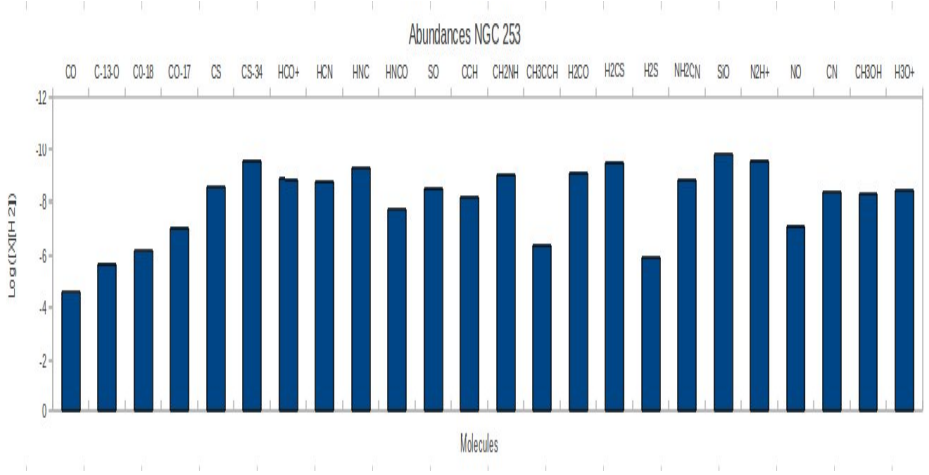
Non LTE molecule

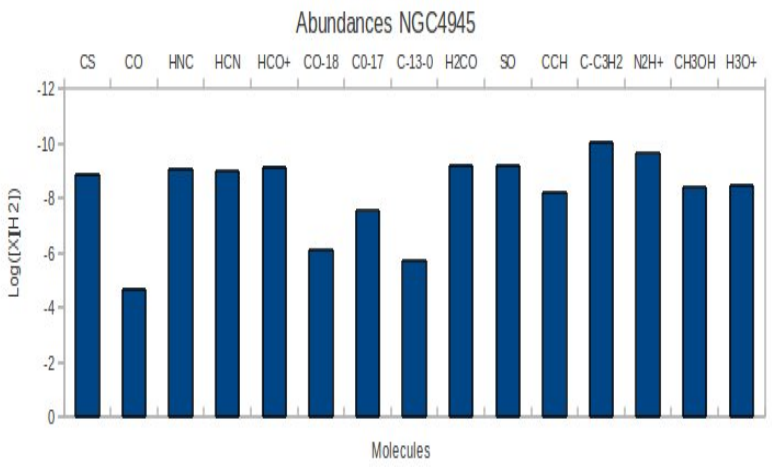
- LTE : The equilibrium of the hot gas in which the radiation emitted is determined by local value of the gas (T, V, P, ...), it change so slowly that we can consider all the system is in local termodinamical equilibrium .
- H_3O^+ - Hydronium, measure of the ionization degree of the gas. Act as a natural filter to select hot molecular gas.
- Recently lines of H_3O^+ were detected in Sgr B2 (Lis et al. 2012) who suggested that the excitation could be due to formation pumping in x-ray irradiated gas.
- Aalto et al. (2011) used the critical density of H_3O^+ transition, it is high, and the low reduced mass of H_3O^+ molecule makes its excitation very sensitive to radiative pumping by dust.
- Maser: Microwave amplification by estimulate emission of radiation.
- Some galaxies have black holes which a disk of molecular material is falling. Excitations of these molecules in the disk or in a jet can result in megamasers, some of that can get luminosities sufficient for detection from external galaxies (different conditions).

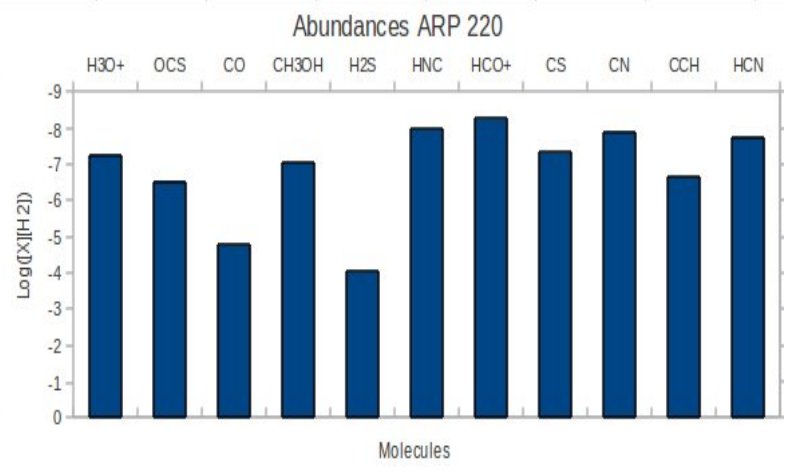
Abundances Comparison

MOLECULE	[X]/[H2]NGC4945	[X]/[H2]NGC253	[X]/[H2]ARP220
CO	2.04^{-5}	2.66^{-5}	$1{,}72^{-5}$
HCN	1.03^{-9}	1.53^{-9}	1.81^{-8}
CCH	6.2^{-9}	6.23^{-9}	2.28^{-7}
CS	1.28^{-9}	2.89^{-9}	4.81^{-8}
HCO+	6.94^{-10}	1.31^{-9}	5.66^{-9}
HNC	8.43^{-10}	4.83^{-10}	1.08^{-8}
CH3OH	4.05^{-9}	5.18^{-9}	9.18^{-8}
H3O+	3.30^{-9}	3.84^{-9}	5.68^{-8}
CO-18	7.88^{-7}	6.99^{-7}	
CO-17	2.97^{-8}	9.05^{-8}	
C-13-O	1.93^{-6}	2.08^{-6}	
H2CO	6.03^{-10}	7.33^{-10}	
SO	6.07^{-10}	2.77^{-9}	
C3H2	8.8^{-11}		
N2H+	2.36^{-10}	2.74^{-10}	
CS-34		2.76^{-10}	
HNCO		1.83^{-8}	
CH2NH		8.46^{-10}	
CH3CCH		4.16^{-7}	
H2CS		3.12^{-10}	
NH2CN		1.52^{-9}	
SiO		1.64^{-10}	
NO		7.42^{-8}	
OCS			2.98^{-7}
H2S			9.34^{-5}
CN			1.33^{-8}

Abundances Comparison







Conclusions

- NGC 4945: It has the most abundant amount of C-18-O, tracer of extended gas.
- NGC 253: It has the most abundant amount of CO, N2H+, HNCO and SiO, tracer of gas temperature, dense gas and shocks.
- ARP 220: It has the most abundant amount of HCN, CCH, HCO+ and HNC, all tracers of very dense gas.
- We can not use LTE to fit H_3O^+ , ν= 364.7974 GHz line is overpopulated. There are two possibilities to explain our results: Radiative pumping or exitence of Maser.
- The isotopic ratio 12C/13C derived from 13C18O and C18O in the starburst galaxies NGC253 and NGC4945 is larger than that found in the nucleus of the Milky Way. There are two possibilities to explain our results: Differences in nucleosynthesis history due to different stellar population history and/or accretion of matter from the halo.
- ILHUIYOLITZIN V.P. et al. (2013), A 1mm spectral line survey of the starburst galaxy NGC253, NGC 4945 and ULIRG ARP220, Astronomy and Astrophysics, in prep.

Thanks, Danke , Gracias, Merci, Grazie!!