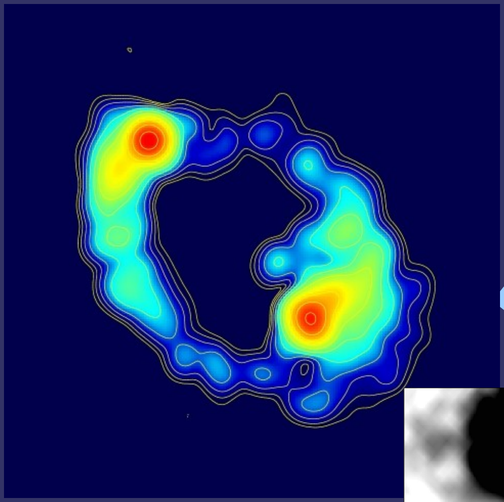
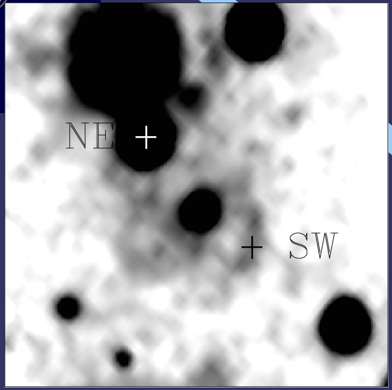
Absorption line surveys at intermediate redshift

"Molecules at z=0.89"





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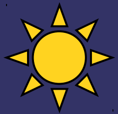
F. Combes, S. J. Curran, P. Theule, S. Longmore

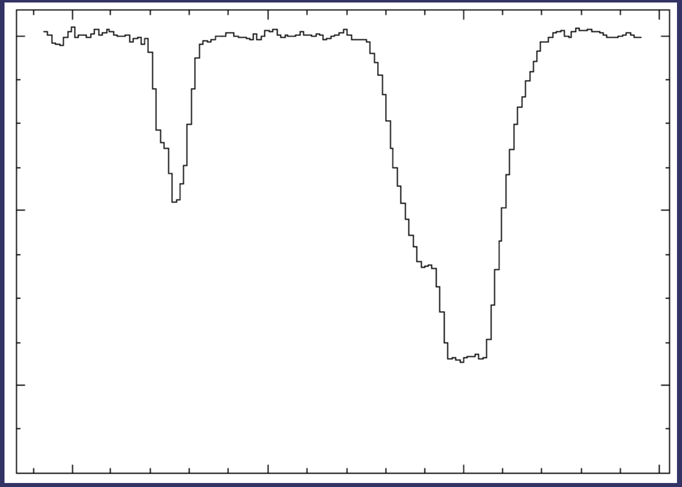
Outline

- Extragalactic radio-mm molecular absorbers
- ATCA 7 mm spectral survey toward PKS1830-211
    - Deep molecular inventory in a z=0.89 galaxy
- Molecular absorbers as cosmological probes
    - Isotopic ratios
    - CMB temperature
    - Variations of fundamental constants
- Time variations
- Perspectives

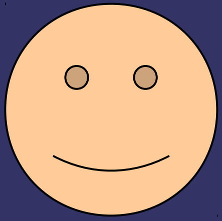


Radio quasar
= Continuum background source

Intervening (or host) galaxy
With molecular gas on the los



Molecular absorption lines



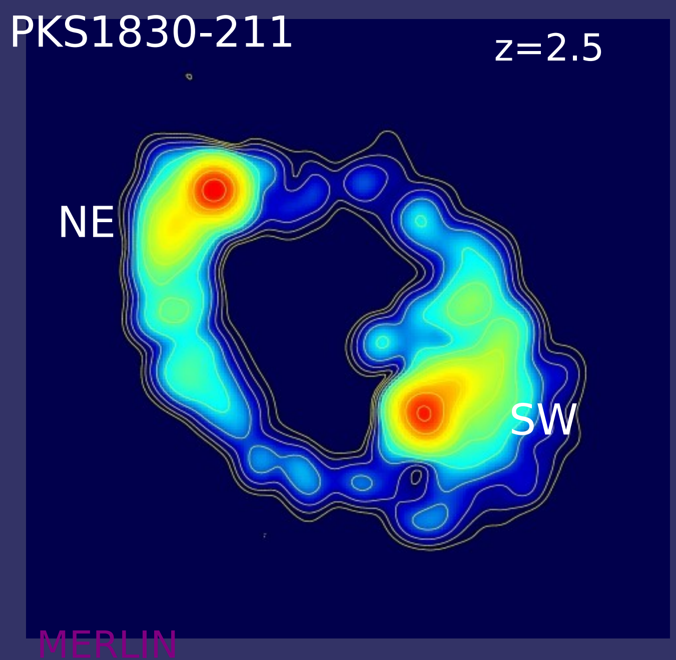
Happy astronomer

Extragalactic radio-mm molecular absorbers

Source	z(abs)	Background continuum flux (Jy)	$N(H_2)$ (cm^{-2})	Molecules detected
Cen A	0.002	6	2×10^{20}	CO, OH, NH_3, CN, HCO^+, HCN, N_2H^+, CS, H_2CO, C_3H_2
3C293	0.045		2×10^{19}	CO, HCO^+, HCN
4C31.04	0.060		1×10^{19}	CO, HCO^+, HCN
PKS 1413+135	0.247	0.5	5×10^{20}	CO, CN, HCO^+, HCN, HNC
B 1504+377	0.673	0.4	5×10^{20}	CO, HCO^+, HCN, HNC
B 0218+357	0.685	0.5 lensed	4×10^{21}	CO, NH_3, H_20, HCO^+, HCN, HNC, CS, H_2S, H_2CO
PKS 0132-097	0.765	0.4		OH (only)
PKS 1830-211	0.886	2-3 lensed	2×10^{22}	34 species (not incl. isotopic variants)

e.g. see review by Combes 2008

PKS 1830-211 and the z=0.89 absorber



Radio Einstein ring ~1" in size

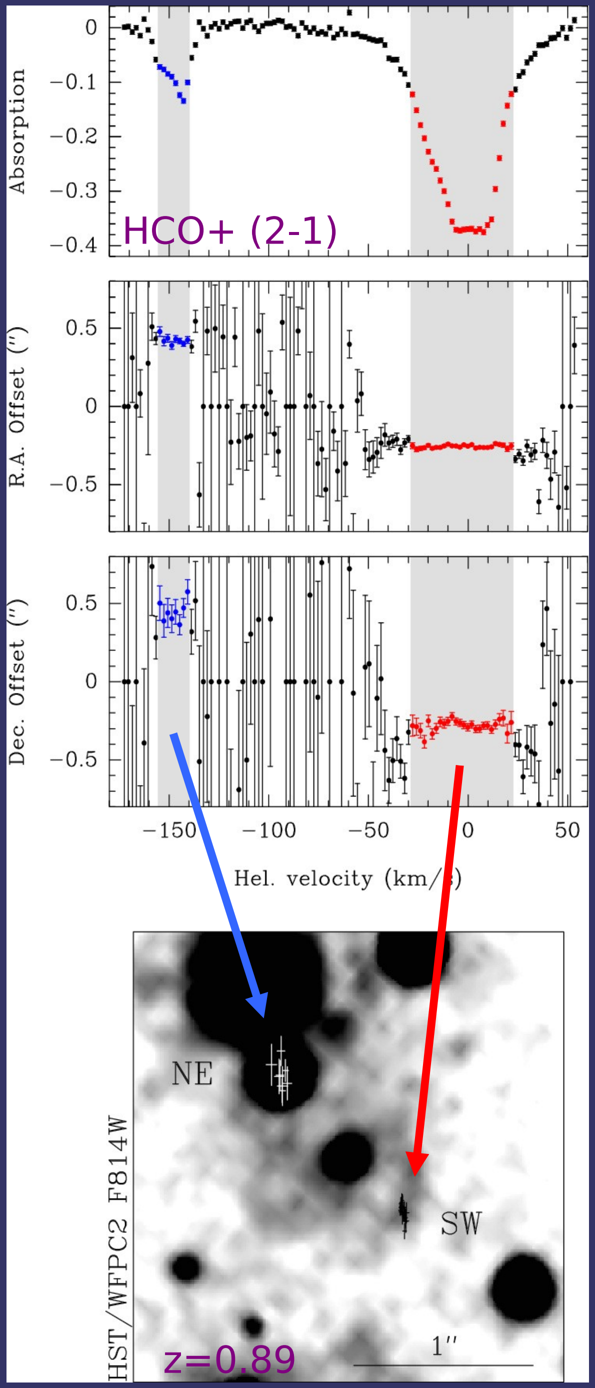
@ 43 GHz

NE and SW cores ~ 0.2 mas

(Jin et al 2003)

Scaling @3 mm, and projected in the plane of the z=0.89 galaxy:

Continuum illumination ~1 pc !



Lens @z=0.89

Face-on spiral galaxy

Molecular absorption along 2 lines of sight:

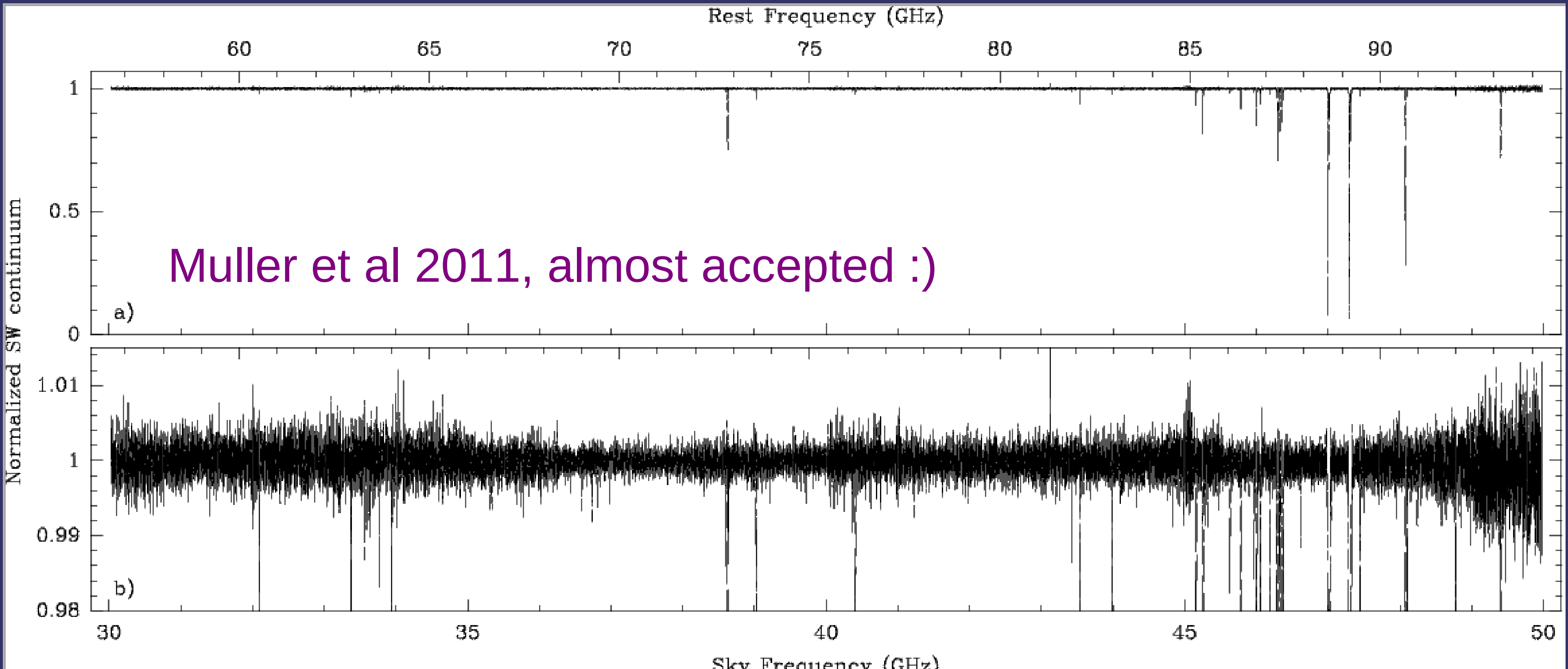
- SW Rgal ~ 2 kpc
  n(H2) ~ 10^{-3} cm^{-2}
  Tkin ~ 50-100 K
- NE Rgal ~ 4 kpc

(Another galaxy @z=0.19 with HI, but no molecular absorption)

PdBI
Muller et al 2006

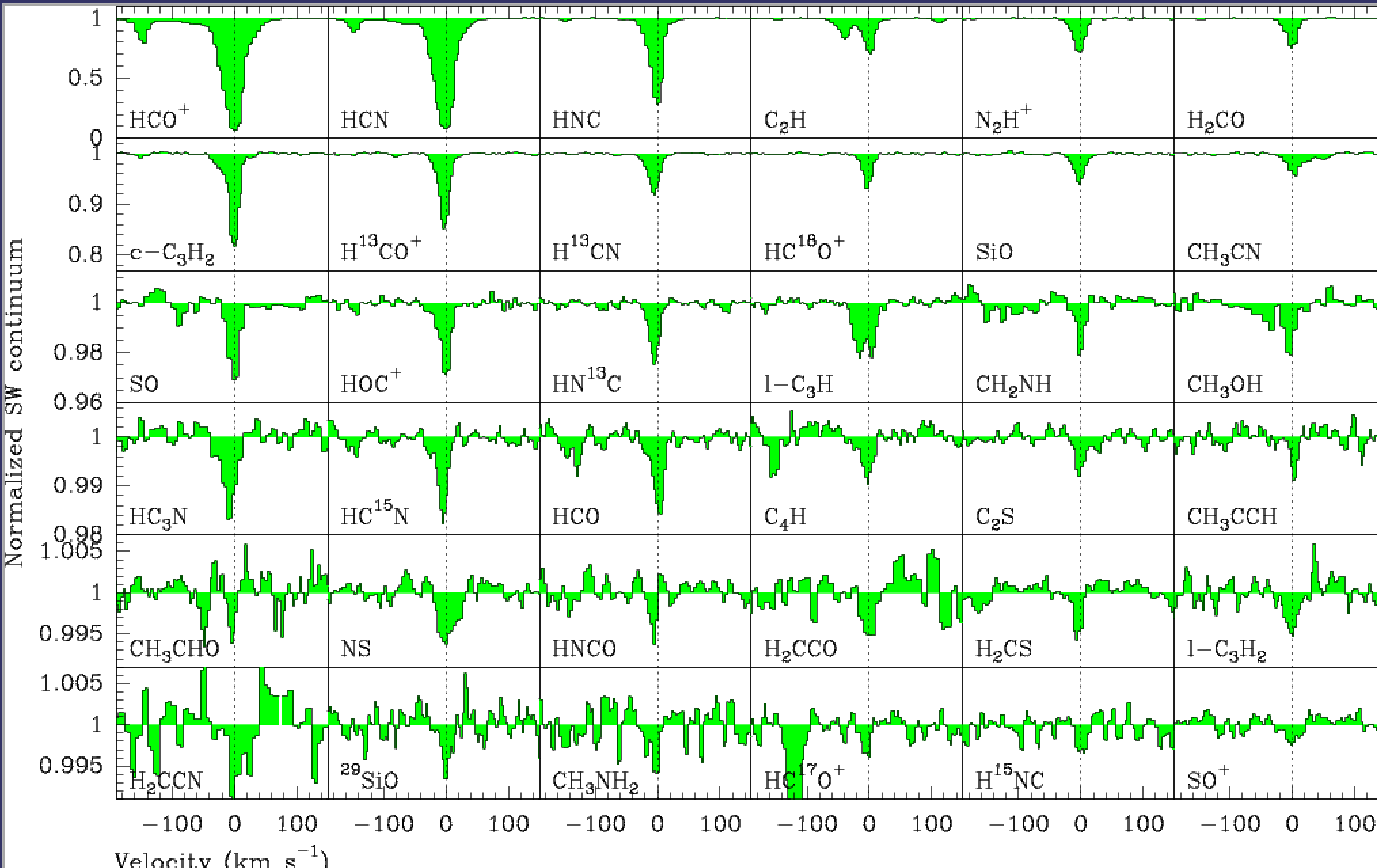
A 7 mm spectral survey toward PKS 1830-211

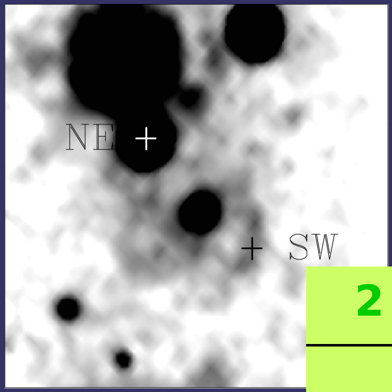
- Covering the frequency interval 30 - 50 GHz (57 – 94 GHz rest frame)
- With ATCA, CABB system, 1 MHz resolution
- Observations in 2009 Sep 1&2, and 2010 Mar 17
- Total on-source integration time < 18h
- Reaching optical depth of a few 10^{-3}



Muller et al 2011, almost accepted :)

A family picture





Molecular inventory @ z=0.89 (SW)

34 species

2 atoms	3 atoms	4 atoms	5 atoms	6 atoms	7 atoms
(OH)	(H_2O)	(NH_3)	CH_2NH	CH_3OH	<u>CH_3NH_2</u>
(CO)	C_2H	H_2CO	c-C_3H_2	CH_3CN	CH_3CCH
(CS)	HCN	<u>l-C_3H</u>	<u>l-C_3H_2</u>		<u>CH_3CHO</u>
SiO	HNC	HNCO	<u>H_2CCN</u>		
NS	N_2H+	H_2CS	<u>H_2CCO</u>		
SO	HCO+		<u>C_4H</u>		
<u>SO+</u>	HCO		HC_3N		
	HOC+				
	(H_2S)				
	C_2S				

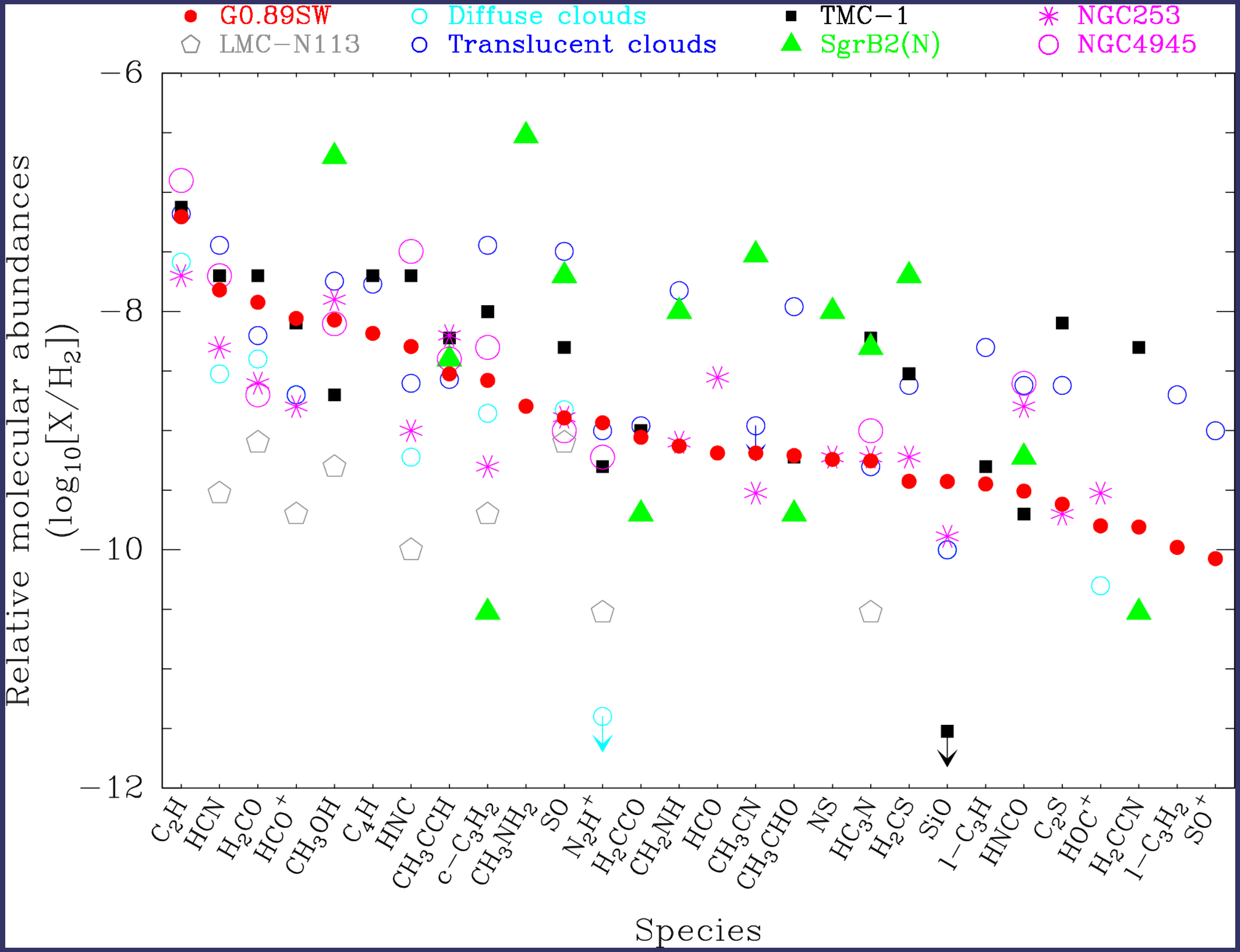
Bias toward species with:

- a high dipole moment
- a low partition function
- low energy transitions within the frequency coverage

- Ions
- Highly reactive radicals
- Unsaturated carbon chains
- Saturated species

-> Active chemistry !

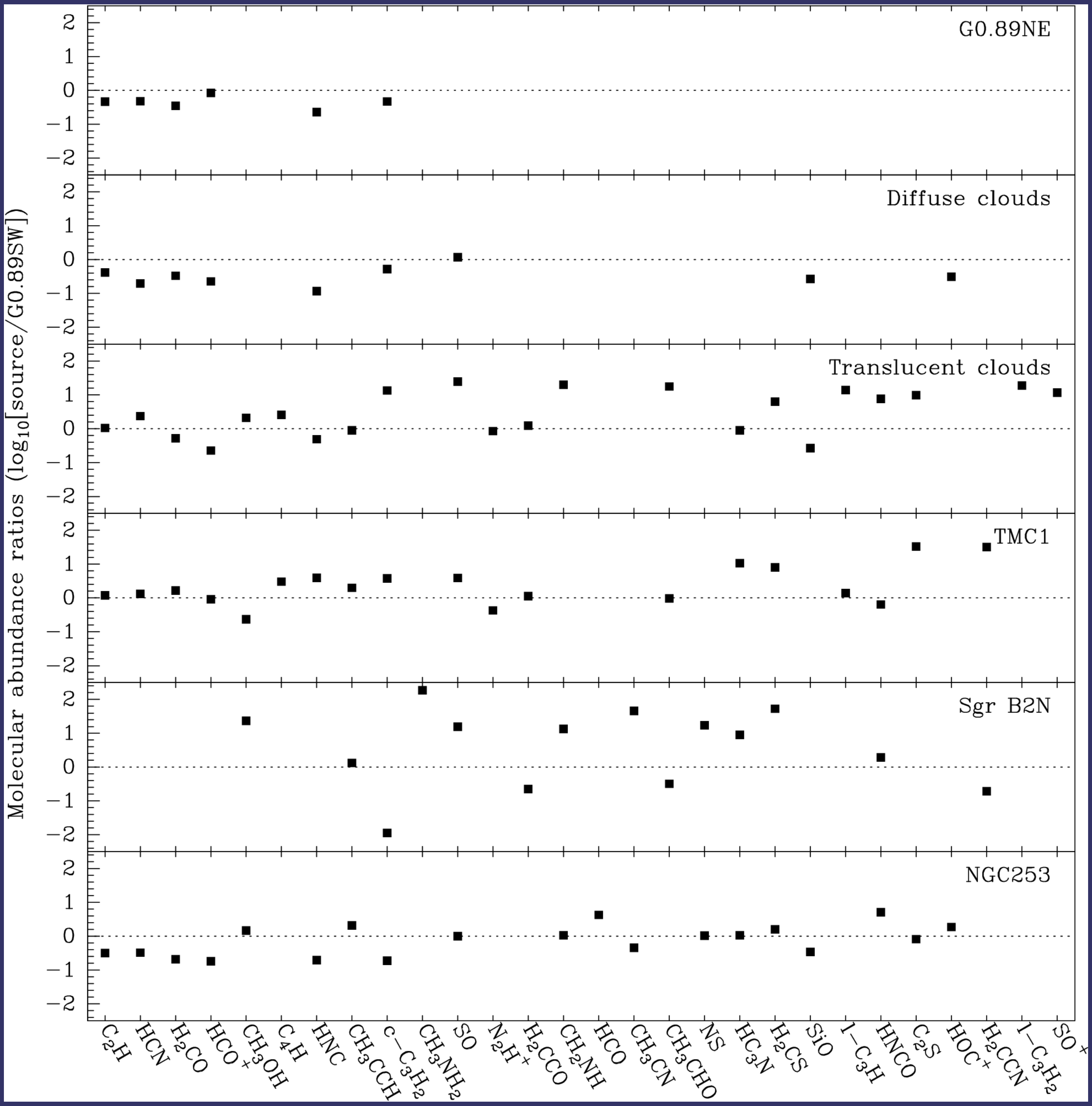
Molecular abundances



Uncertainties:

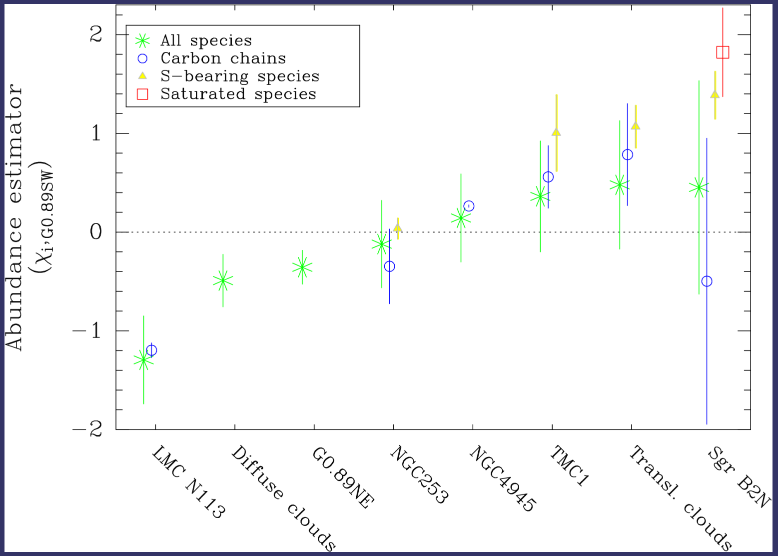
- Background continuum and covering factor
- H2 column density
- Are species co-spatial ?
- Excitation and opacity effects

Comparative chemistry



Abundance richness estimator

$$\chi_{ij} = \frac{1}{N_{mol}} \sum_{k=1}^{N_{mol}} \log_{10}\left(\frac{X_{i,k}}{X_{j,k}}\right)$$



SW: abundances intermediate between those in diffuse and translucent Galactic clouds

NE: similarity with diffuse clouds

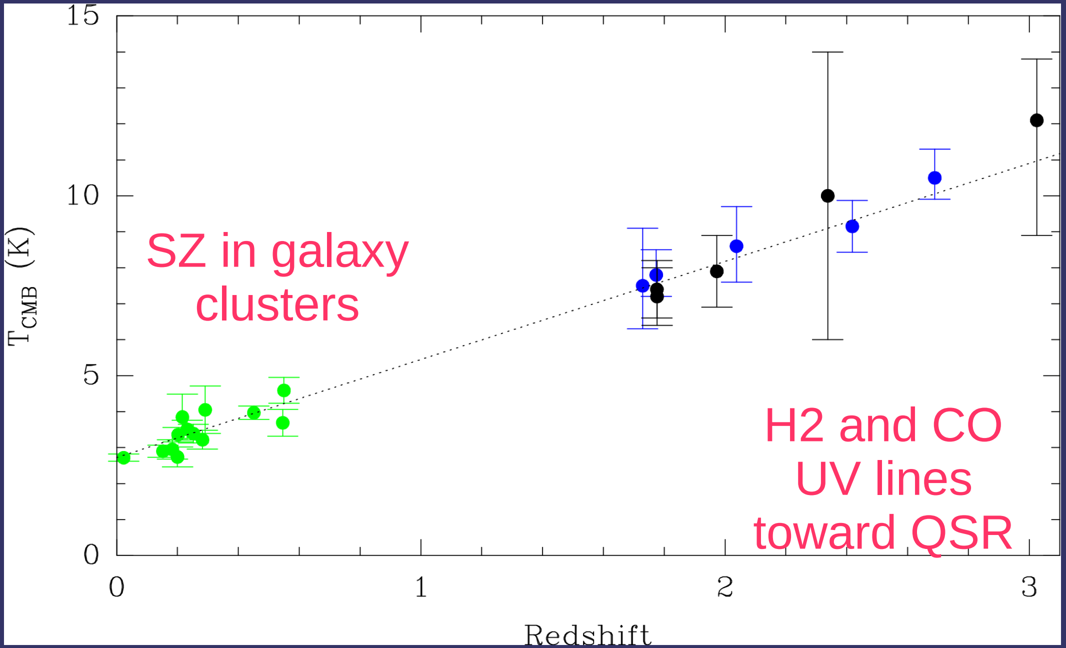
Isotopic ratios

	12C/13C	14N/15N	16O/18O	18O/17O	32S/34S	
z=0.89	35 ± 11 32 ± 6	190 ± 60 143 ± 30	80 ± 25 66 ± 12	20 -7,+4 12 –2,+3	- 10.5 ± 0.6	@7mm @3mm
NGC4945	50 ± 10	105 ± 25	195 ± 45	6.4 ± 0.3	13.5 ± 2.5	
NGC253	40 ± 10	--	200 ± 50	6.5 ± 1	8 ± 2	
Solar System	89	270	490	5.5	22	
Local ISM	59 ± 2	237 -21,+27	672 ± 110	3.65 ± 0.15	19 ± 8	
Galactic Center	25 ± 5	900 ± 200	250 ± 30	3.5 ± 0.2	18 ± 5	
IRC+10216	45 ± 3	> 4400	1260 -240,+315	0.7 ± 0.2	21.8 ± 2.6	

- D/H < 7 x 10^{-4} (no fractionation enhancement)
- Surprising results for 12C/13C, fractionation ?
- At high-z, enrichment dominated by short-lived massive stars (similar to SB ?)
- In the long term, effects of low-mass stars
- Preliminary results at z=0.68 follow the same trend (Muller et al in prep.)

Cosmic Microwave Background

T_{CMB} *vs* z



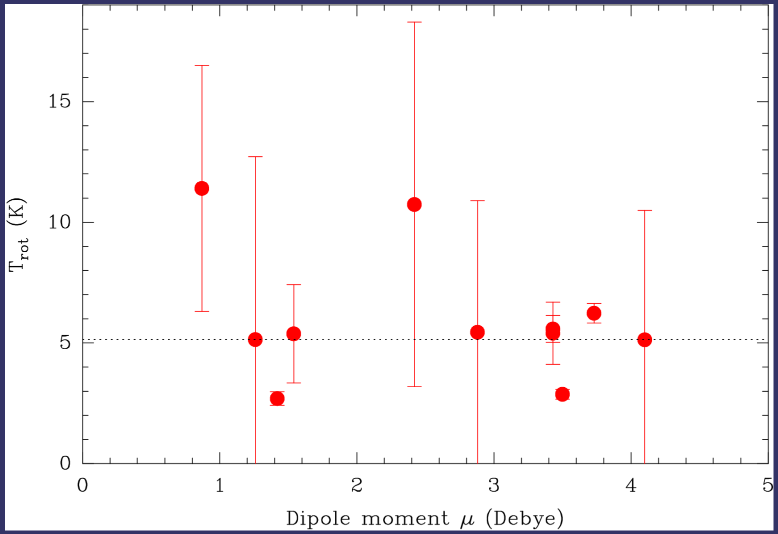
e.g. Noterdaeme et al 2011 and ref. therein

$$T_{CMB} \propto (1+z)^{1-\alpha}$$

- Adiabatic expansion : $\alpha = 0$
- Models of decaying dark energy: $\alpha > 0$
  (e.g. Lima 1996, Jetzer 2010)

At low density, Trot couple with the radiation field

From ATCA data, (LTE) Trot measurements for: HC_3N, c-C_3H_2, C_2S, l-C_3H_2, SO, H_2CCO, H_2CCN, C_4H, CH_3CHO, CH_3NH_2



→ T_{CMB} @ z=0.89 (Muller et al in prep.)

Probing variations of fundamental constants of Physics

$\mu = m_p / m_e$

A variation in μ would introduce a velocity offset between lines with different frequency dependence in μ: $\Delta V_{ij} / c = (K^{\mu}_{i} - K^{\mu}_{j}) \Delta\mu/\mu$

- For rotational lines, $K^{\mu} = -1$
- For inversion lines of **ammonia**, $K^{\mu} = -4.46$ — Flambaum & Kozlov 2007

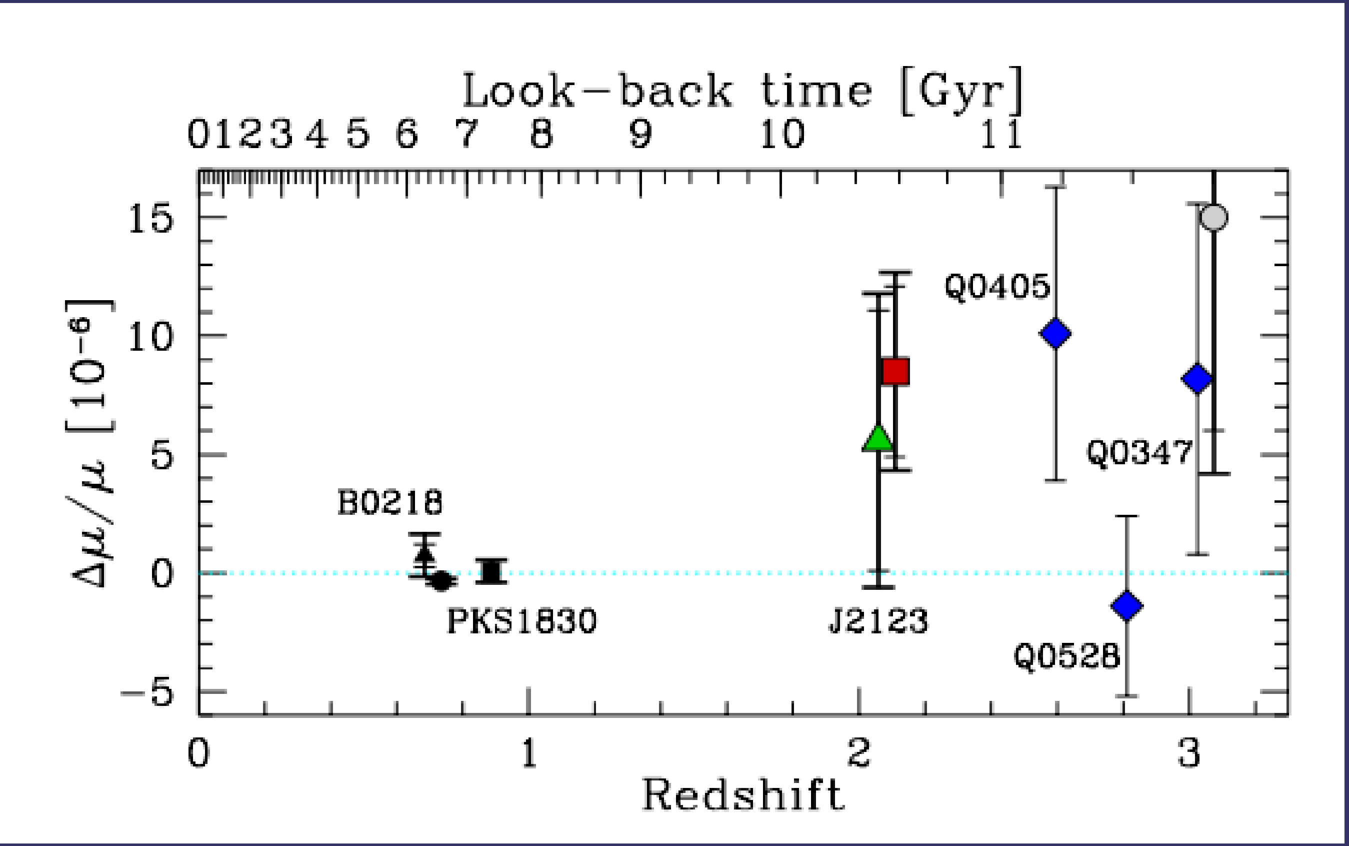
- Lines of **methanol** have different sensitivities K^{μ} — Jansen et al 2011

  e.g. CH3OH @ 60.531 GHz, $K^{\mu} = -7.4$

Method	Target	$\Delta\mu/\mu$	Ref.
inv.NH_3 vs (HCO^+, HCN)	B0218+357 z=0.68	$< 1.8 \times 10^{-6}$	Murphy et al 2008
inv.NH_3 vs HC_3N	PKS1830-211 z=0.89	$< 1.4 \times 10^{-6}$	Henkel et al 2009
inv.NH_3 vs (CS, H_2CO)	B0218+357 z=0.68	$< 3.6 \times 10^{-7}$	Kanekar 2011
inv.NH_3 vs (average of 22 species)	PKS1830-211 z=0.89	$< 2.2 \times 10^{-6}$	Muller et al 2011
CH_3OH vs (average of 22 species)	PKS1830-211 z=0.89	$< 1.4 \times 10^{-6}$	Muller et al 2011

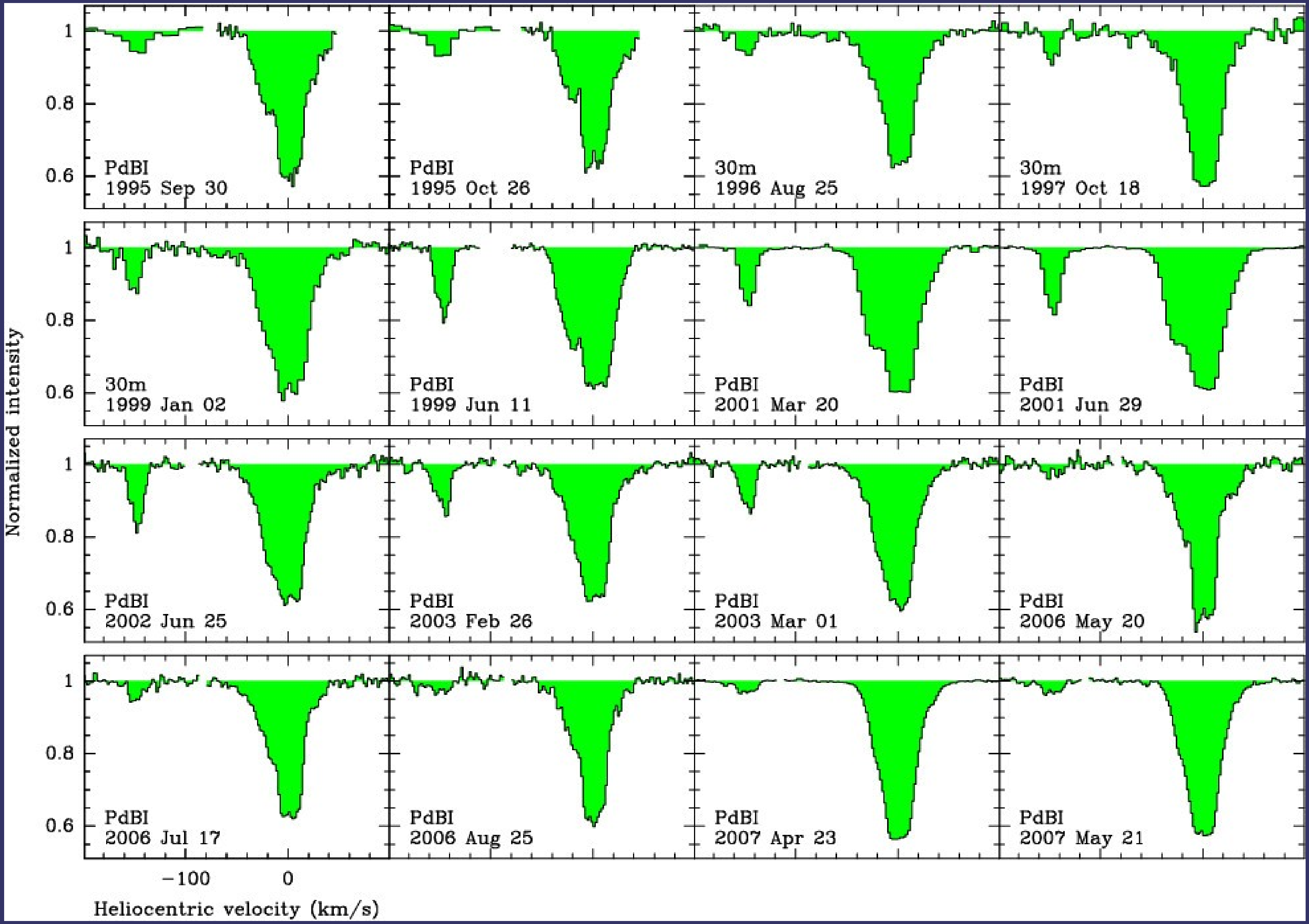
Notion of ”chemical noise”

Δμ/μ and other measurements



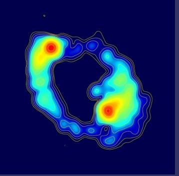
van Weerdenburg et al 2011

Time variability of the absorption profile

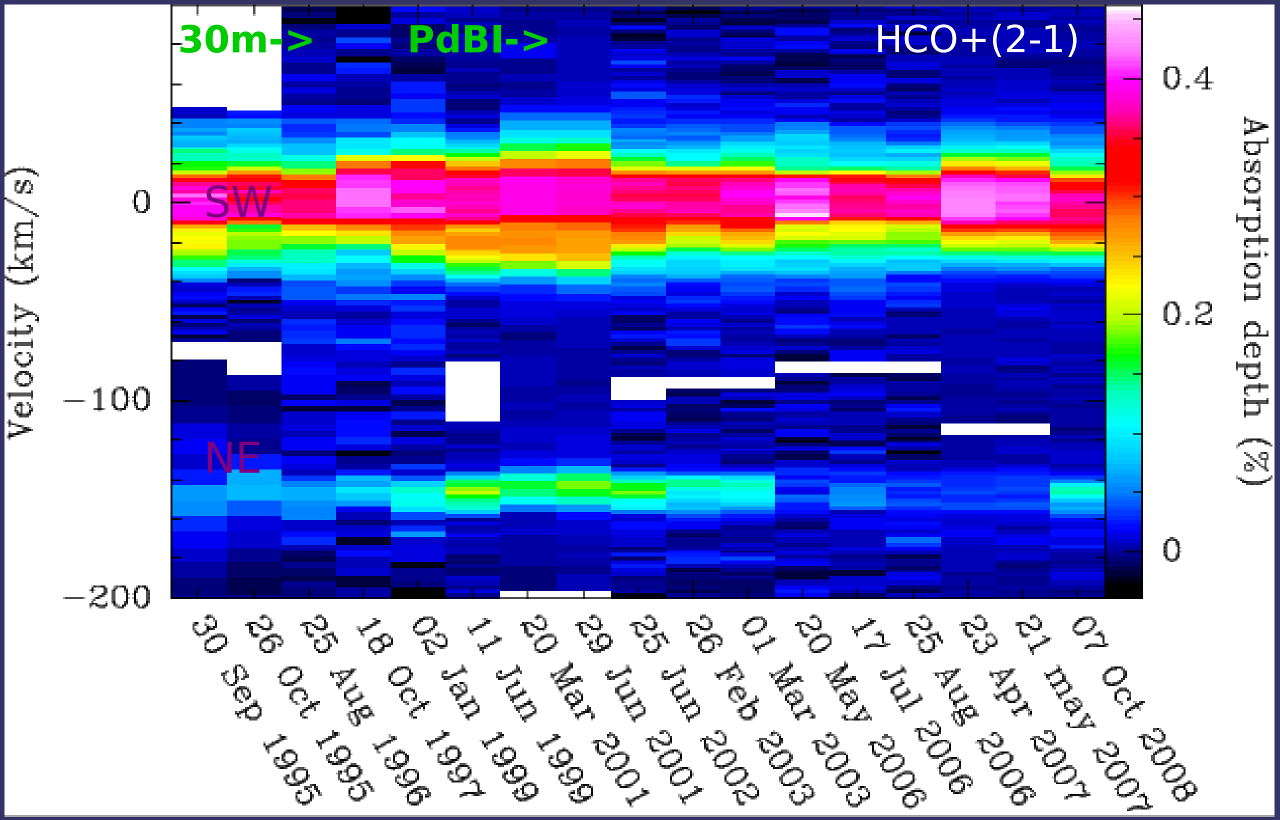


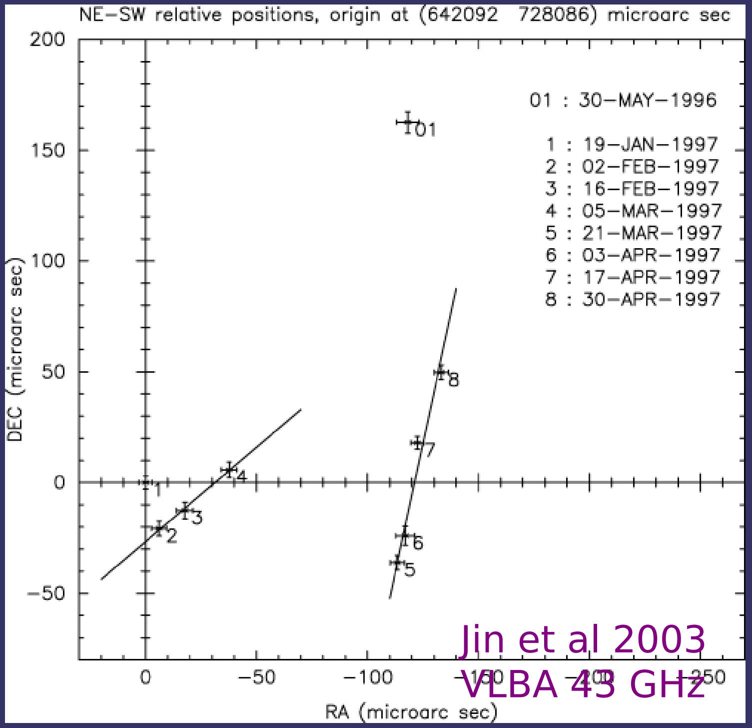
HCO+ 2-1

Muller & Guélin 2008



Time variability





Jin et al 2003

Relative positions of the
NE – SW continuum sources

Changes of the NE-SW distance of up to 0.2 mas within 8 months (Jin et al 2003)

Interpretation :

Recurrent ejection of plasmons along a helicoidal jet (Nair et al 2005)

Monitoring of absorption lines :

-> potential to study the structure of GMCs at z=0.89

-> spatial correlation for different species

Perspectives

- Chemical inventory of molecular absorbers
  - Molecules difficult to observe from the ground @ z=0
- Study of gas properties in distant galaxies
- Cosmological probes
  - Enrichment history (isotopic ratios)
  - T_{CMB} as a function of z
  - Variations of fundamental constants
- Search for new absorbers !
- EVLA, ALMA ...

EVLA Key Science Project toward PKS1830-211

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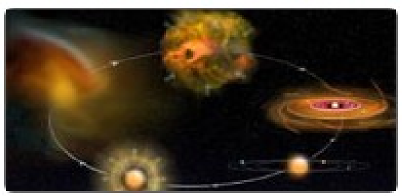
Science > Key Science > Unbiased K/Ka/Q-band Absorption Survey towards B1830-210

Unbiased K/Ka/Q-band Absorption Survey towards B1830-210

An Unbiased K, Ka, and Q-band Absorption Survey at z = 0.88582 towards B1830-210
E. Momjian (NRAO), N. Kanekar (NRAO), D. Meier (NRAO)



Using the expanded frequency coverage of the EVLA, this group proposes an astrochemical study of a high redshift galaxy. Apart from a handful of simple molecules, very little is known about the molecular environment at high redshift. This project will trace all molecular species with rest frequencies in the 34 to 93 GHz range and provide an unprecedented view of the molecular environment at high redshift. Beyond the significant astrochemical and cosmological interest, this study would be a unique demonstration of the new continuous spectral coverage and high spectral resolution of the EVLA.

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More and bigger molecules ?
Certainly interesting results !