Science from the G333 Survey

Insights into the chemistry and dynamics of star formation from multi-molecular line surveys

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The G333 multi-molecular line survey

Mapping of 0.6 x 1.2º region of the southern Galactic plane with Mopra.

G333 – a giant molecular cloud complex with active star formation.

- 2004: ^{13}CO
- 2005: $C^{18}O$
- 2006: CS, HCN, HNC, HCO^+, HC_3N, SiO, SO, CH_3OH, N_2H^+ and some of the isotopes
- 2007: 80 – 116 GHz broad band mapping of seven selected sources

Motivations

- Study the turbulence structure of molecular cloud complex
- Study the effect of turbulence on chemistry
- Do different densities tracers have different turbulent properties

Results of

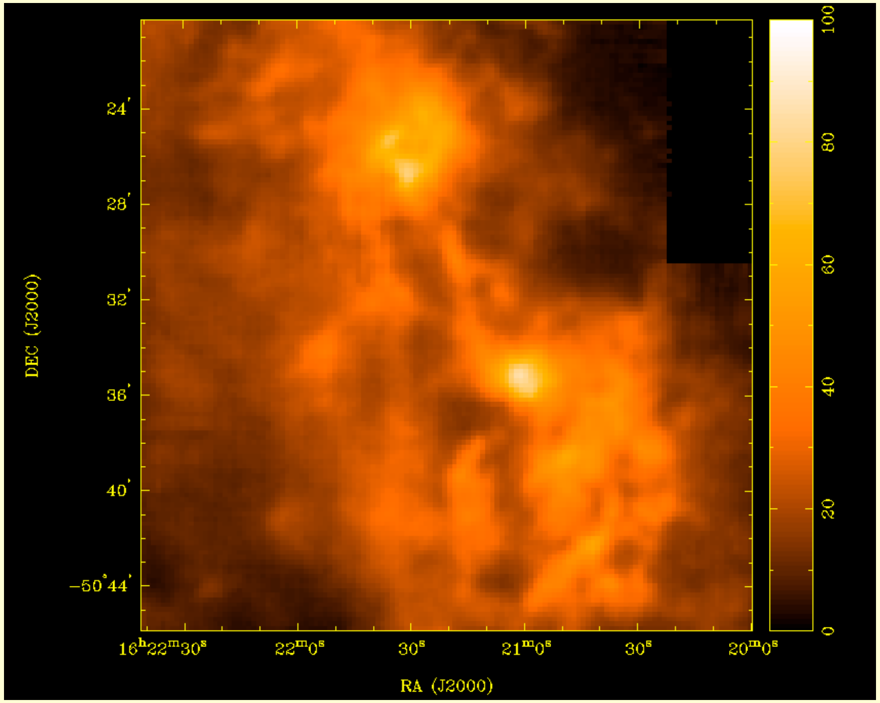
1. Spatial power spectrum (SPS) [Paul Jones]
2. Principal component analysis (PCA)

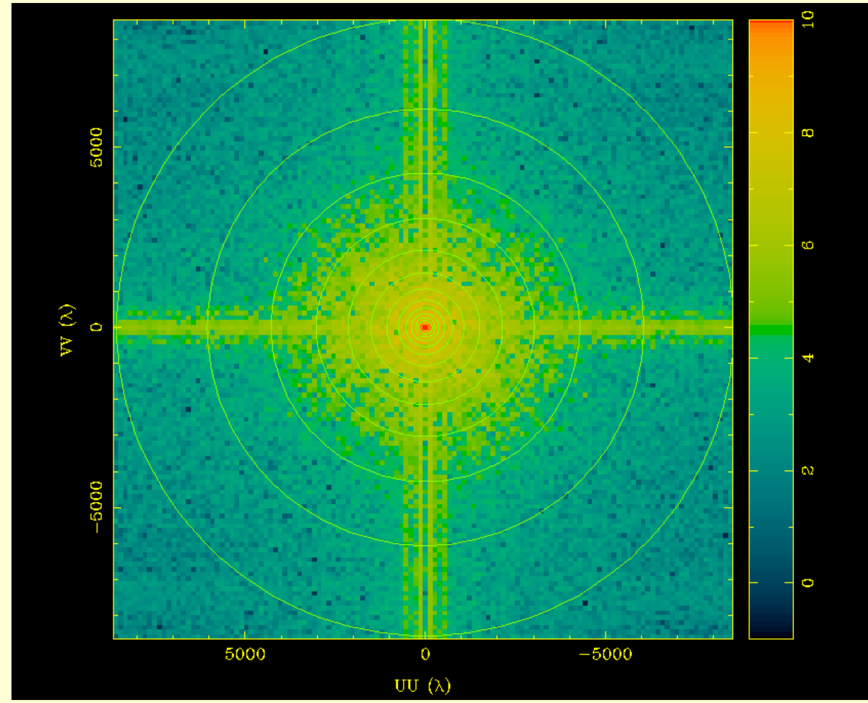
Spatial power spectrum

- Power (P) in an image as a function of spatial scale
- With the G333 data set:

1) Take the integrated emission map of data cube
2) Then Fourier Transform the 2D image
3) Power is the square of the amplitude (A) of the FT image,

$$P = A^2 = (Re)^2 + (Im)^2$$

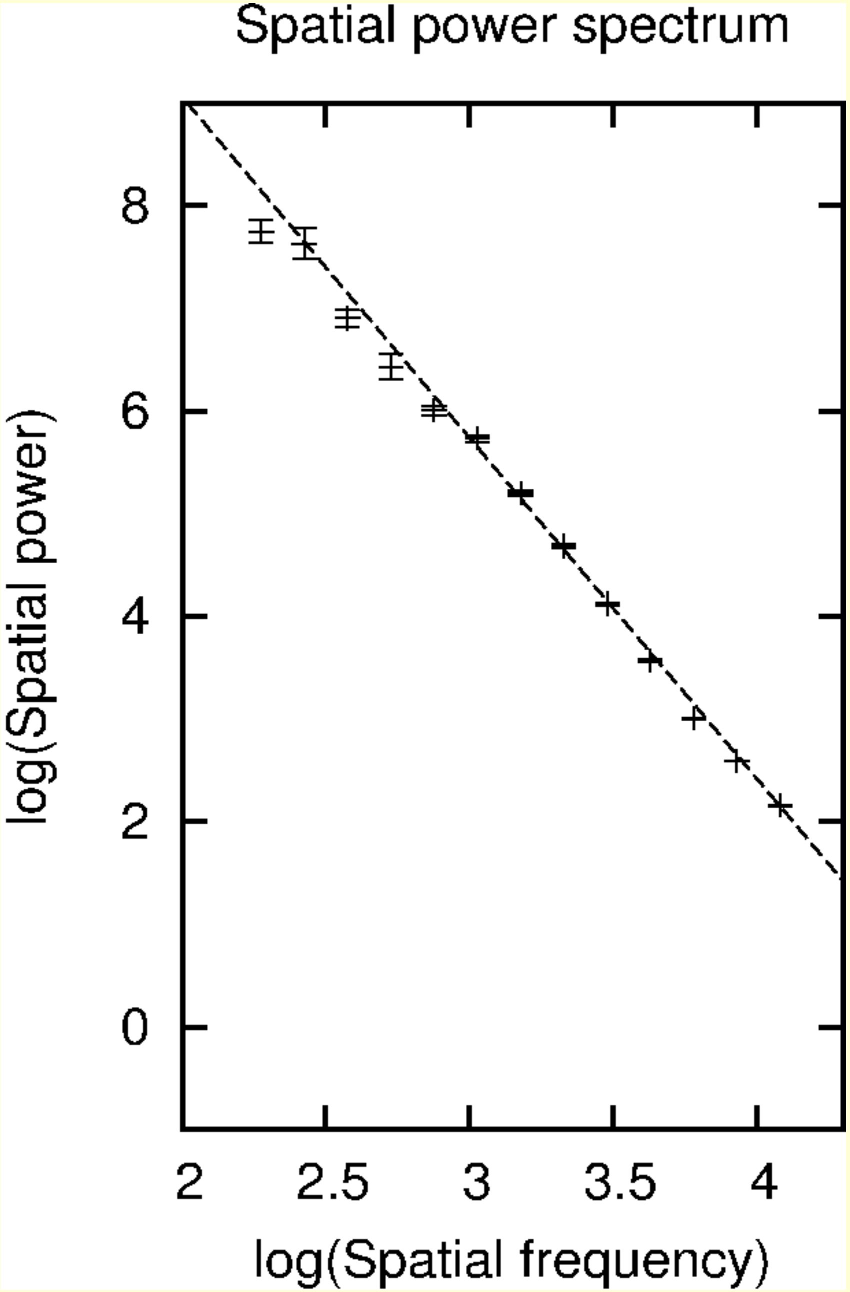




128 x 128 pixel image (^{13}CO)
(RA, Dec)

128 x 128 pixel FT power
(wavenumbers)

- calculate the average power for a given scale, from an annulus in the FT plane (logarithmic bins)

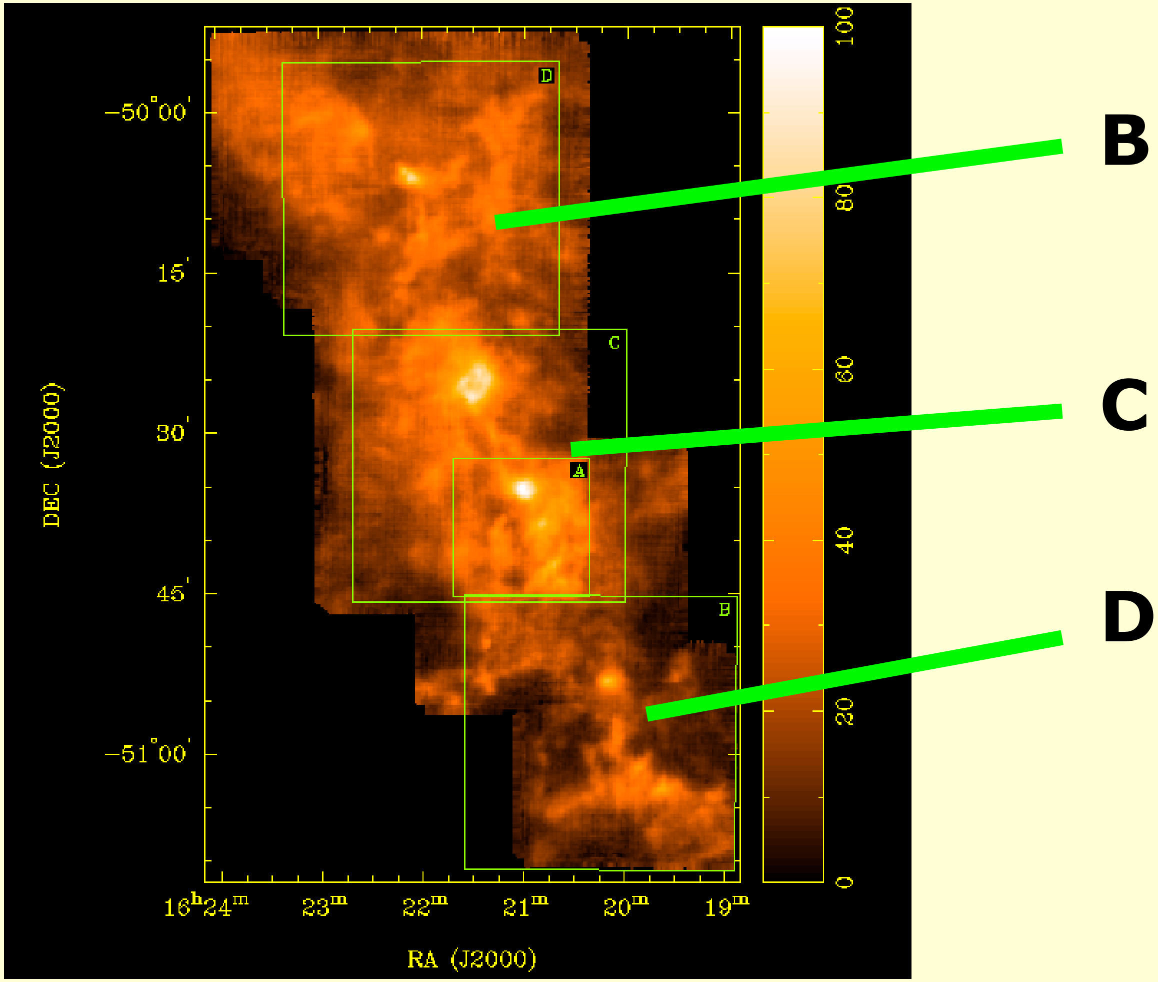


- plot as log(P) vs log(k), to show large range of P and k

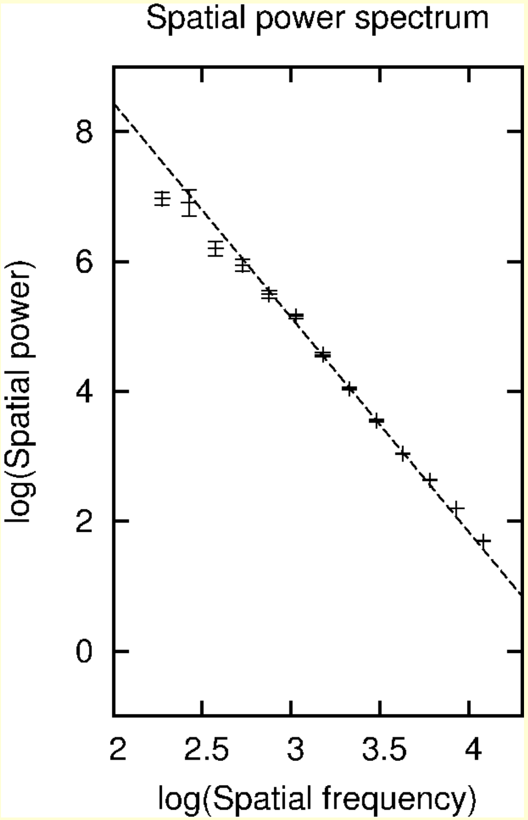
- fit power law (straight line in this plot) as this is good model

Spatial power spectrum

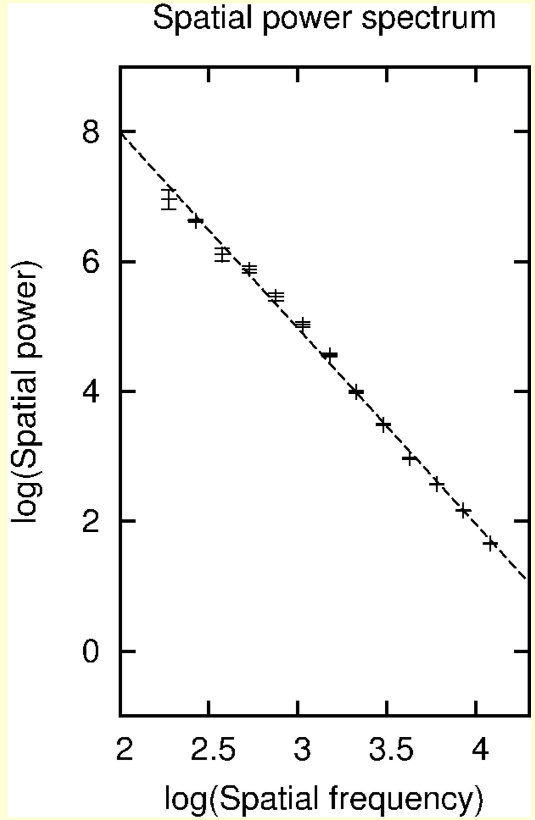
^{13}CO



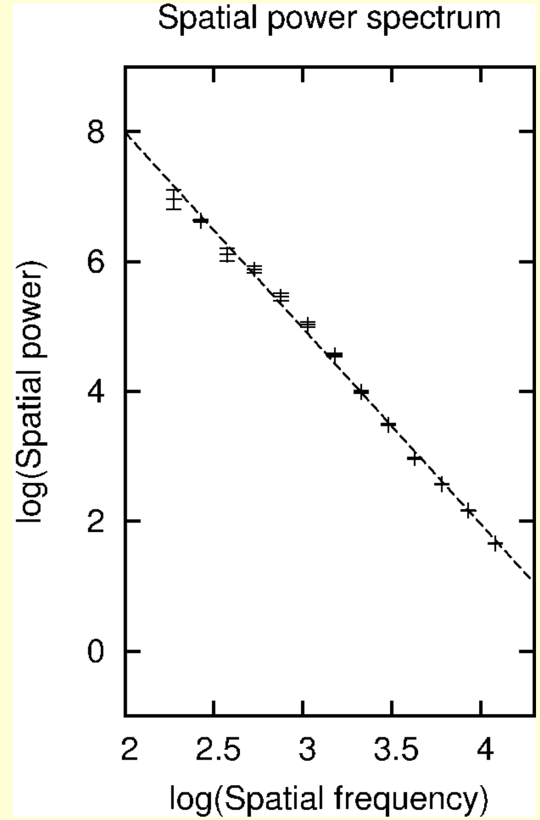
Power Law SPS



B



C

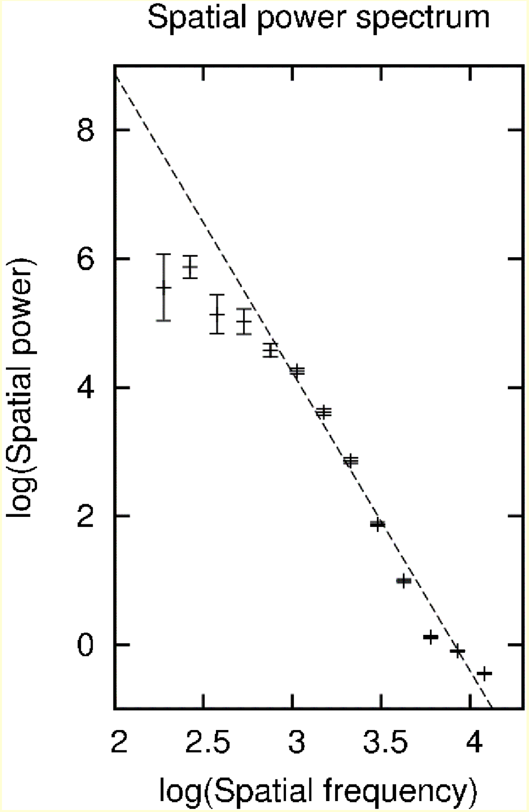


D

^{13}CO mean for 64 channels (~ 1 - 20 pc)

Slope
(mean for areas B, C and D,
integrated emission, noise corrected)

^{13}CO	-3.8
$C^{18}O$	-3.6
corrected ^{13}CO	-3.4
CS	-4.2
HNC	-3.9
HCO^+	-4.0
HCN	-4.1
N_2H^+	-3.4



Similar power law slopes, indicating 'fractal' structure, without **major** breaks in power, except some indication of deficit of large-scale power e.g. CS here, which may give poorer fit to power law, c.f 3-D Kolmogorov = -11/3 = -3.7

Jones et al. (in prep)

SPS results

- The data generally fit a good power law (scales ~1 to 20 pc),
  3-D Kolmogorov = -11/3 = -3.7
- The slope depends on the area within the G333 complex
- The slope does NOT change much for the different molecules (perhaps surprisingly)
- BUT there is a deficit of large-scale power for molecules other than CO

Principal component analysis

- Multivariate data analysis technique
- Look for linear combinations between variables, to reduce the dimensionality of a data set
- Common technique for finding patterns in high dimension data, i.e. pattern recognition

Apply to multi-molecular line data

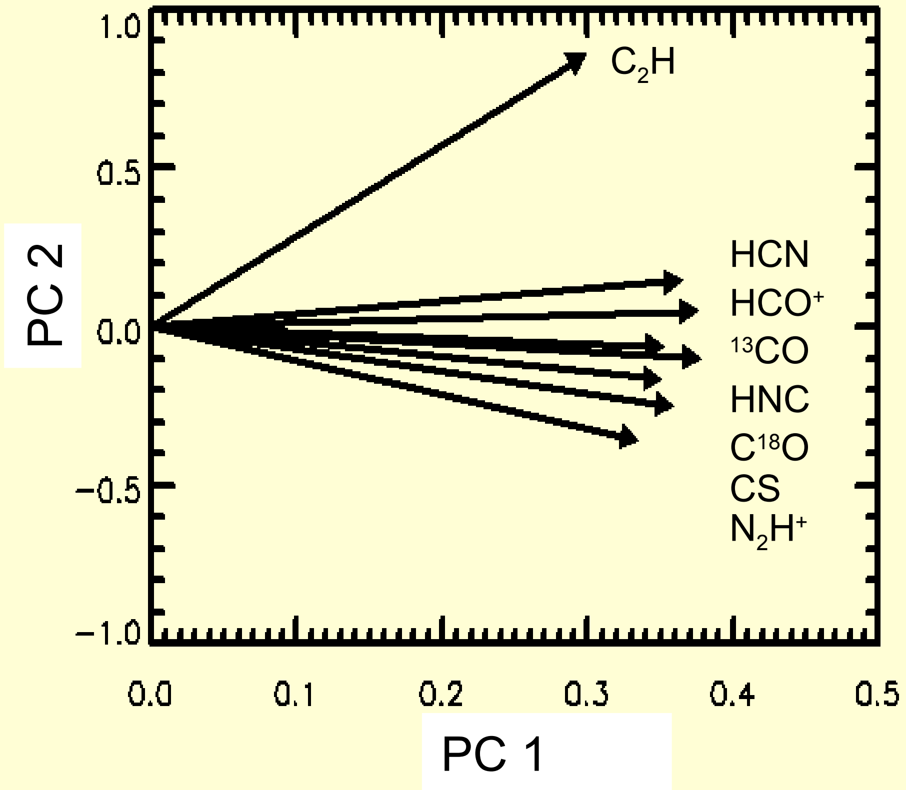
- Look for correlation between different molecules
- Apply to integrated emission maps, study the spatial distribution differences in molecules
    - (Ungerechts *et. al.* 1997)

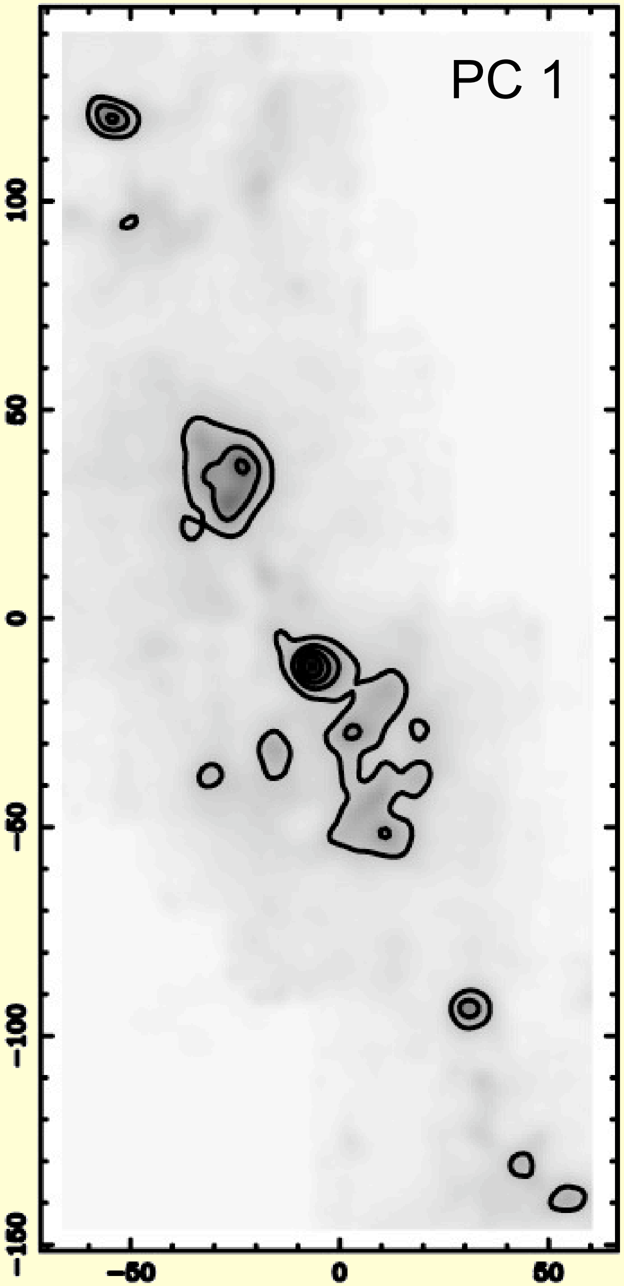
Results

Correlation matrix

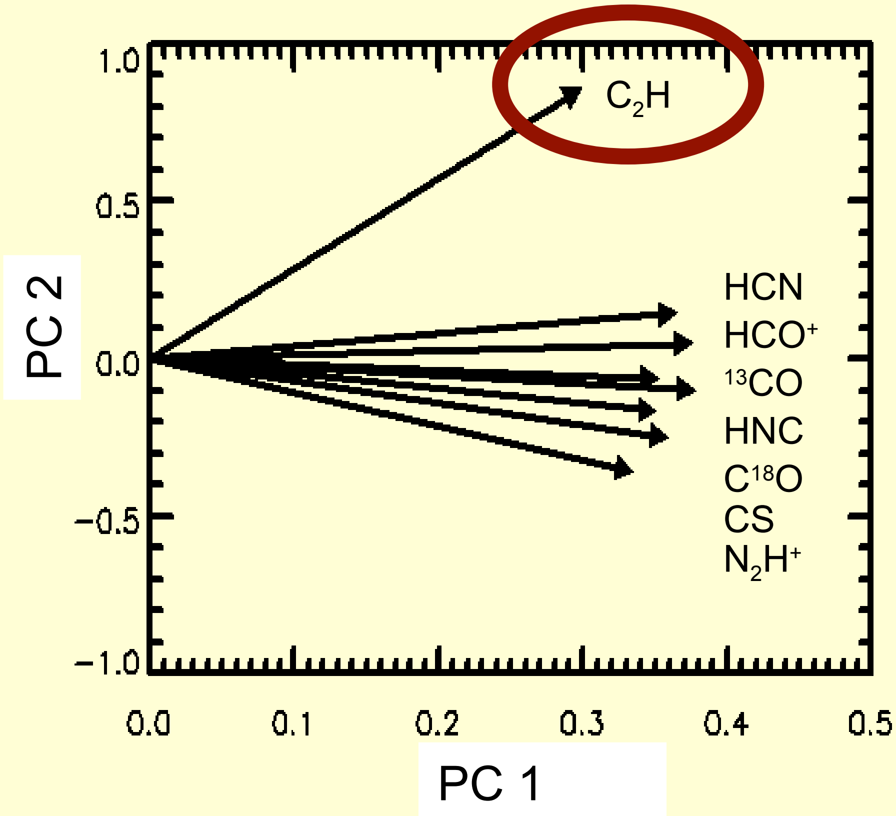
	CS	HCO^+	HNC	$C^{18}O$	C_2H	HCN	N_2H^+	^{13}CO
CS	1.00							
HCO^+	0.85	1.00						
HNC	0.90	0.92	1.00					
$C^{18}O$	0.77	0.80	0.81	1.00				
C_2H	0.60	0.70	0.67	0.61	1.00			
HCN	0.81	0.94	0.90	0.75	0.70	1.00		
N_2H^+	0.80	0.76	0.82	0.73	0.56	0.71	1.00	
^{13}CO	0.77	0.82	0.81	0.88	0.63	0.79	0.69	1.00

Results

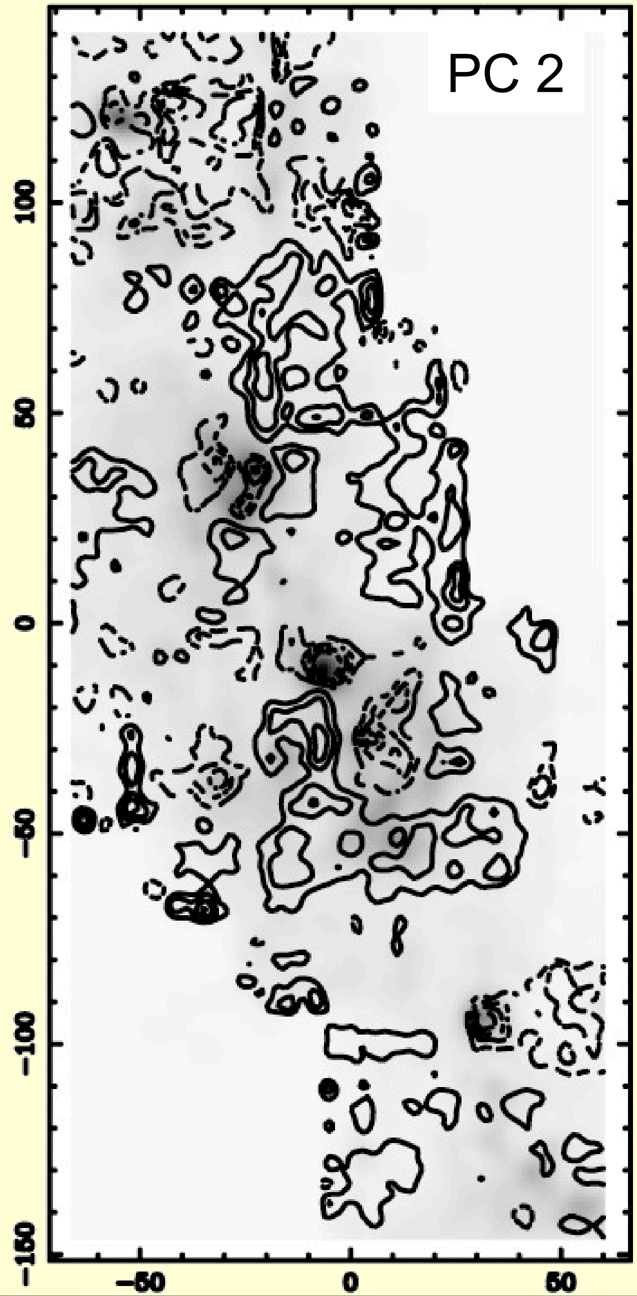

C2H
HCN
HCO+
13CO
HNC
C18O
CS
N2H+
PC 2
PC 1
1.0
0.5
0.0
−0.5
−1.0
0.0
0.1
0.2
0.3
0.4
0.5


PC 1
100
50
0
−50
−100
−150
−50
0
50

Results

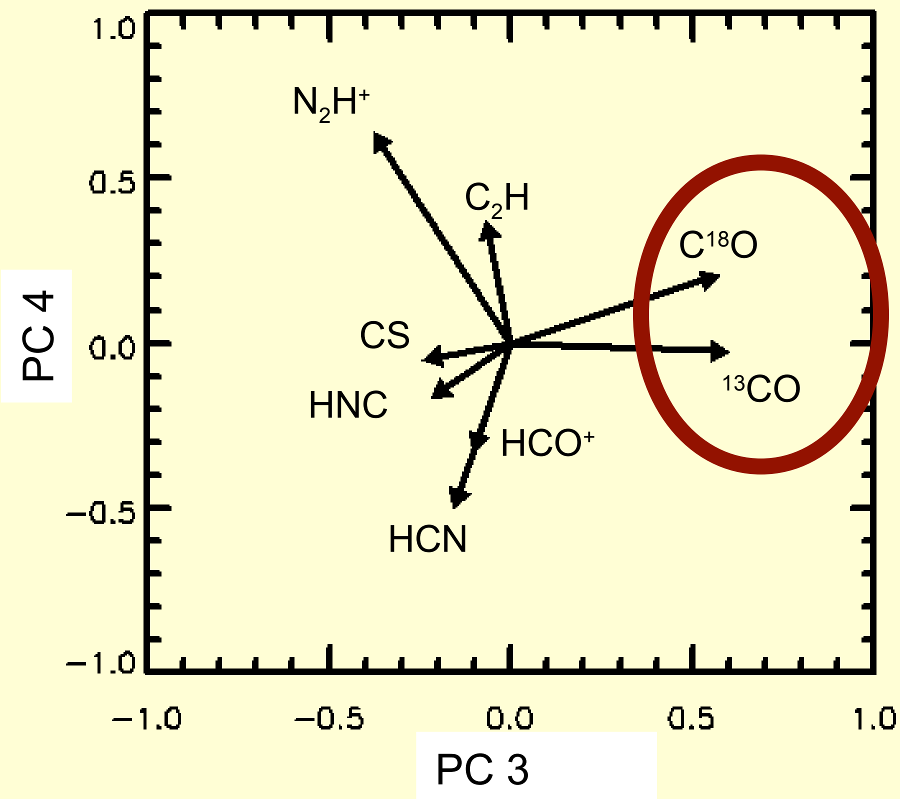


C$_2$H
HCN
HCO$^+$
^{13}CO
HNC
C^{18}O
CS
N$_2$H$^+$
PC 2
PC 1
1.0
0.5
0.0
−0.5
−1.0
0.0
0.1
0.2
0.3
0.4
0.5

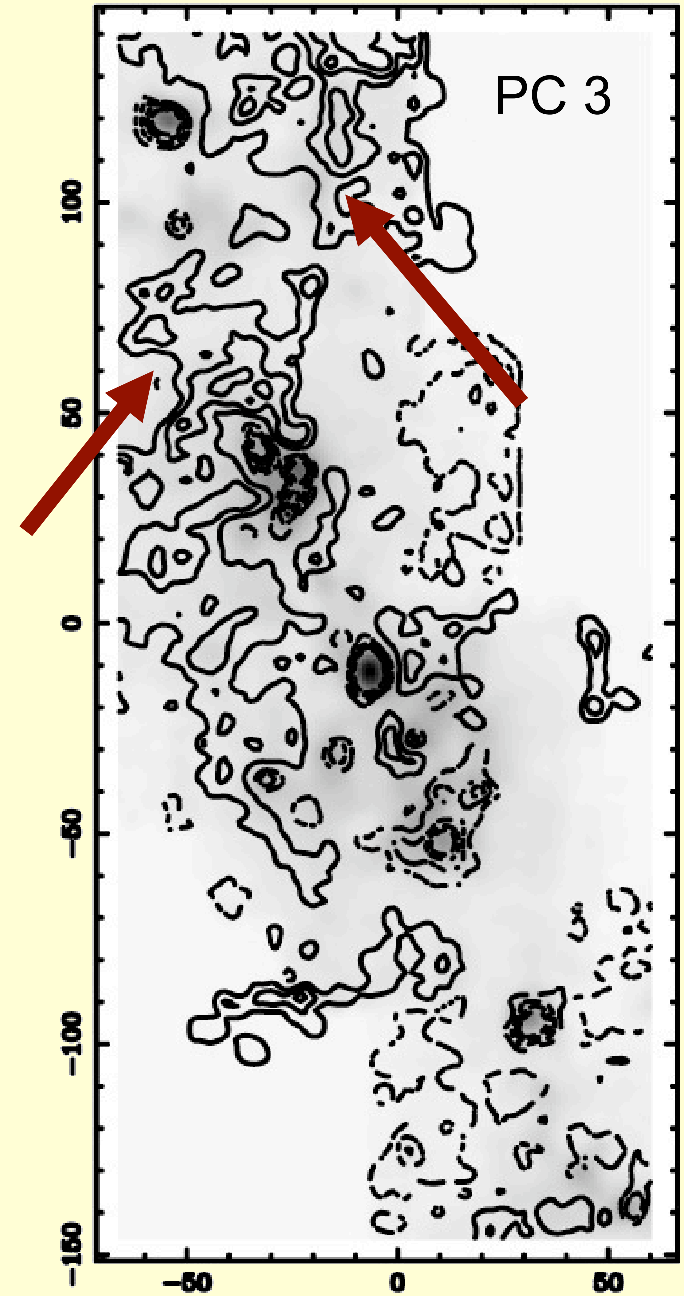


PC 2
100
50
0
−50
−100
−150
−50
0
50

Results

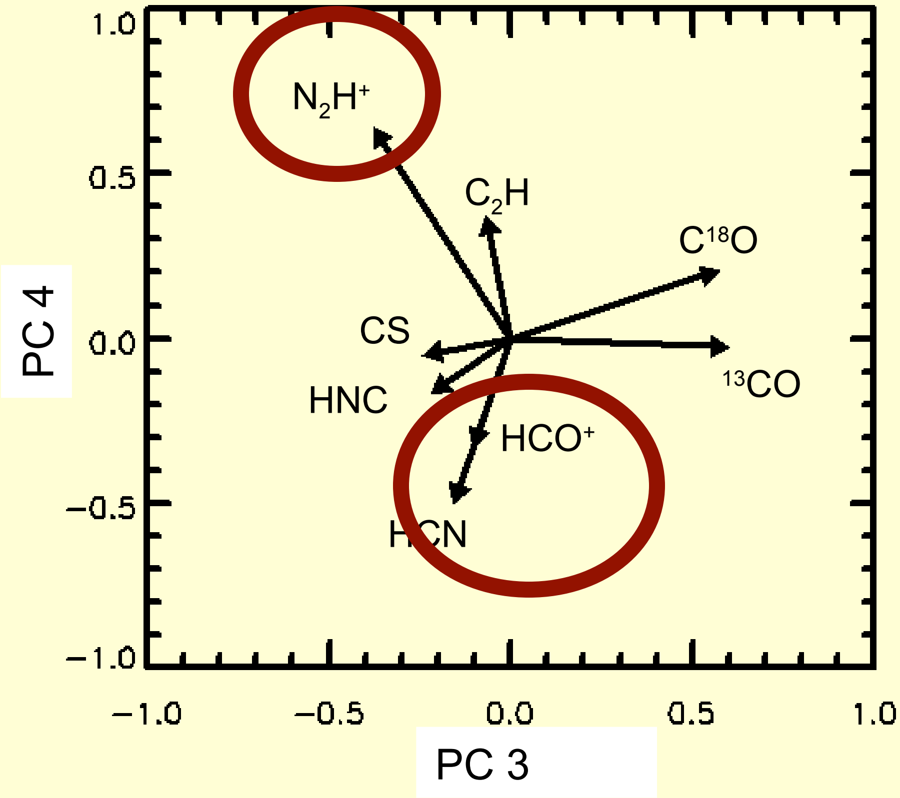


N$_2$H$^+$
C$_2$H
C^{18}O
CS
^{13}CO
HNC
HCO$^+$
HCN
PC 4
PC 3
1.0
0.5
0.0
−0.5
−1.0

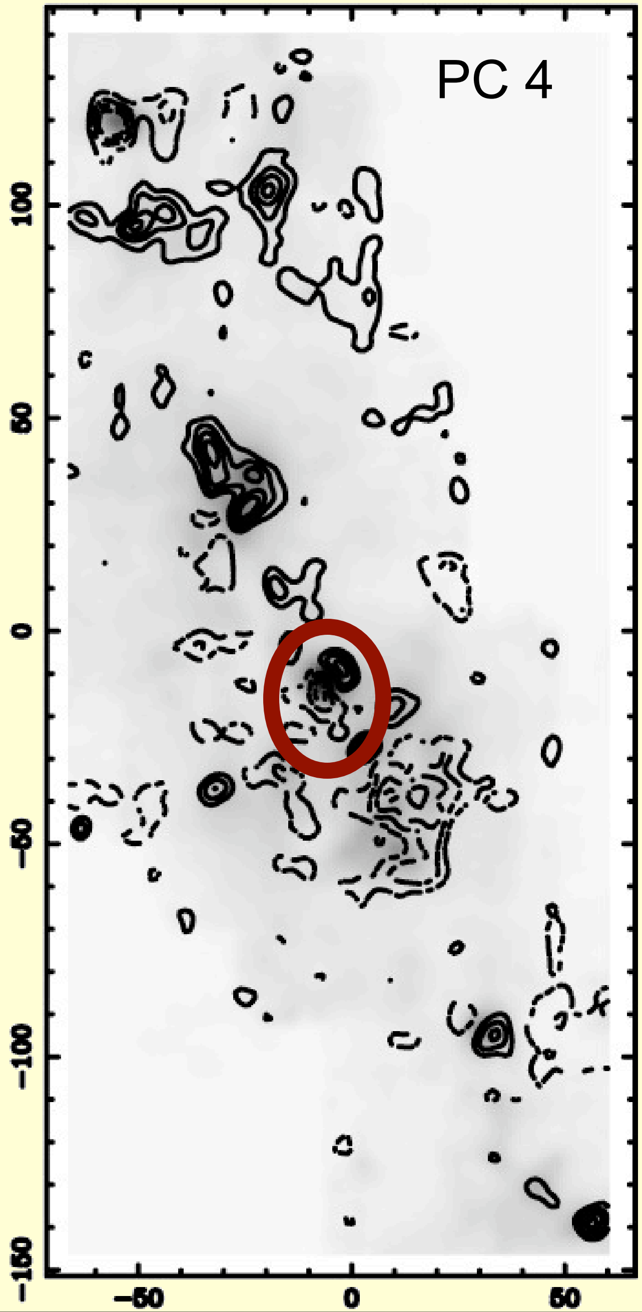


PC 3
100
50
0
−50
−100
−150
−50
0
50

Results

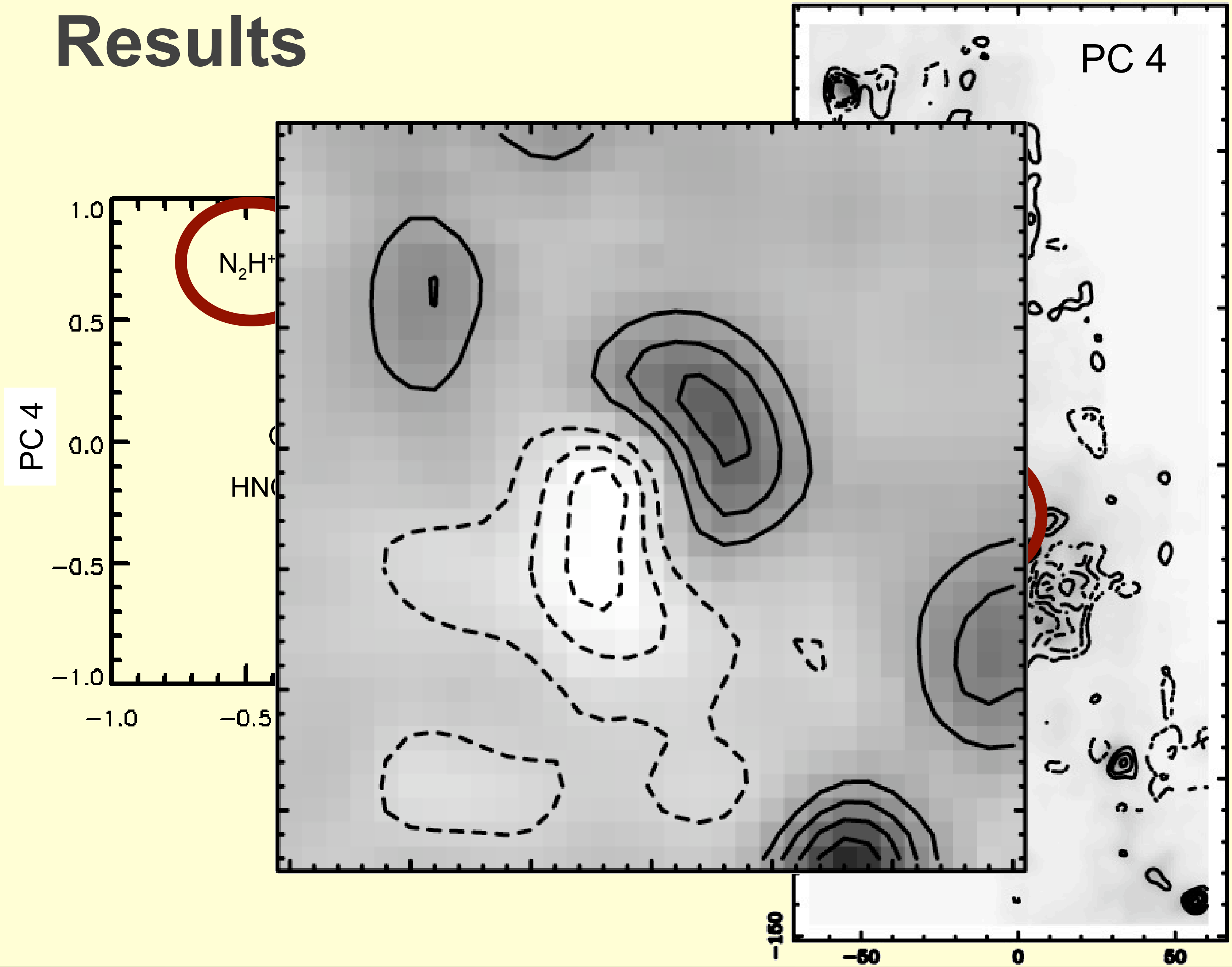


1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0
PC 4
PC 3
N2H+
C2H
C18O
CS
HNC
13CO
HCO+
HCN



PC 4
100
50
0
−50
−100
−150
−50
0
50

Results



Summary

- From SPS, the ISM traced by different molecules has similar statistical structure, even if there are differences in the molecular distribution as shown by PCA.
- The slope is similar to Kolmogorov turbulence slope,

  $$-11/3 = -3.7$$

- On the scales that we are probing (~1 to 20 pc), there are some signs that high density tracers (molecules other than CO) are missing the most extended structure