Clump populations in Rosette spatially associated from CO and dust maps

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What could we learn from clump decomposition?

Veltchev et al. (2017; to be submitted very soon)

- **Why clumps?**
  Clumps as possible (star forming or non-star forming) subfragments of filaments in molecular clouds.

- **Why** GAUSSCLUMPS**?**
  Hierarchical (DENDROGRAM) vs. non-hierarchical (e.g., CLUMPFIND) approaches to disentangle cloud structure.

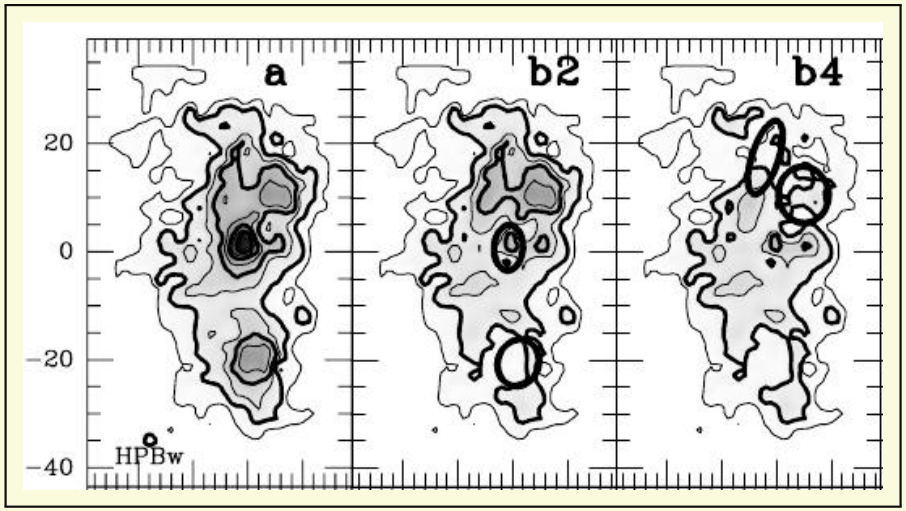
- **Why spatial association (identification)?**
  The crucial role of structure tracer: sensitive to the variety of density regimes in the cloud.

- **Why the star-forming region Rosette?**
  Intensively investigated, mapped at different wavelengths with high angular resolution.

Clump characteristics and association

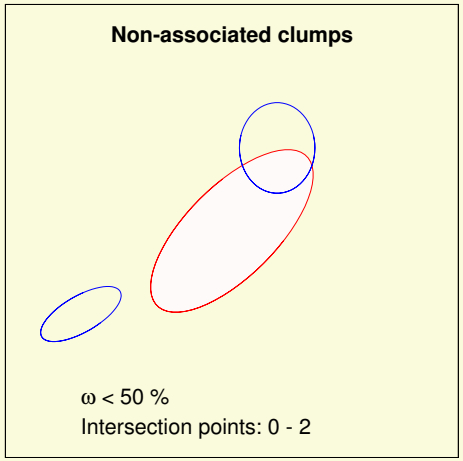
- Data: FCRAO (^{12}CO, ^{13}CO; $20'' \sim 0.12$ pc) (Thank to: M. Heyer & J. Williams);

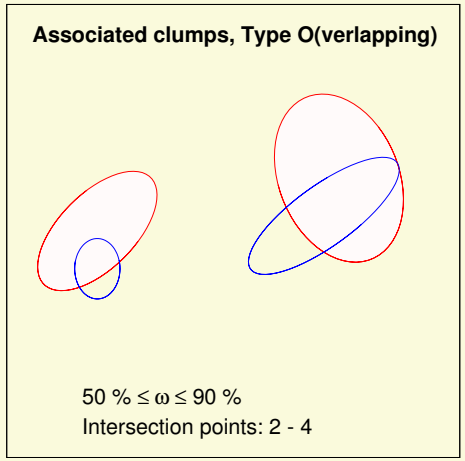
  HERSCHEL(SPIRE, PACS; $36'' \sim 0.2$ pc)
- Extraction method: GAUSSCLUMPS (Stutzki & Güsten 1990, Kramer et al. 1998)
- Clump sizes and masses:
  $D_{\rm cl} = \sqrt{\Delta x\, \Delta y}$; (beam-deconvolved)
  $M_{\rm cl}({\rm CO}) \propto \mu X\, T_0\, D_{\rm cl}^2\, \sigma_v$;
  $M_{\rm cl}({\rm dust}) \propto \mu N_0\, D_{\rm cl}^2$;

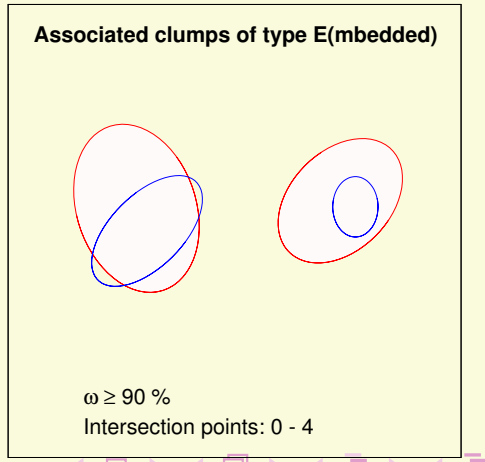


(Adopted from Kramer et al. 1998)

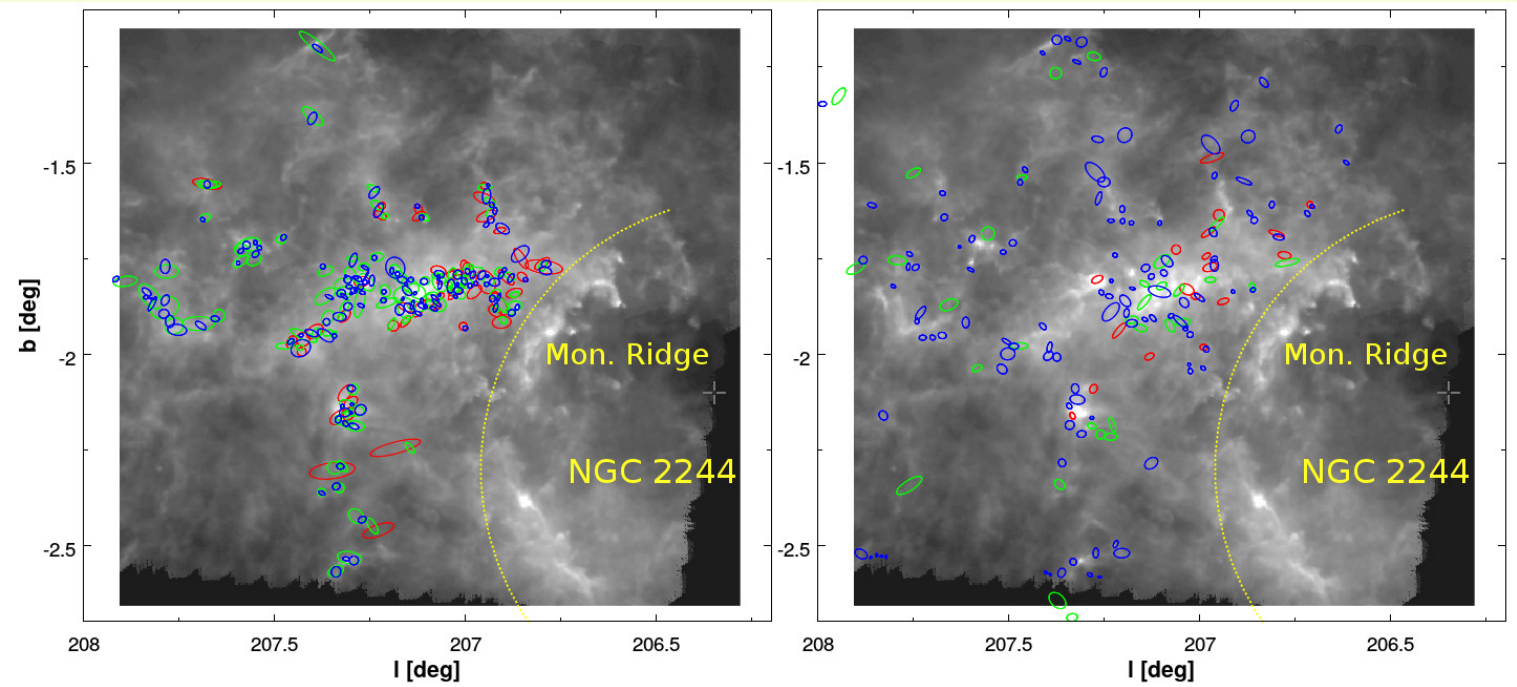
Association criteria







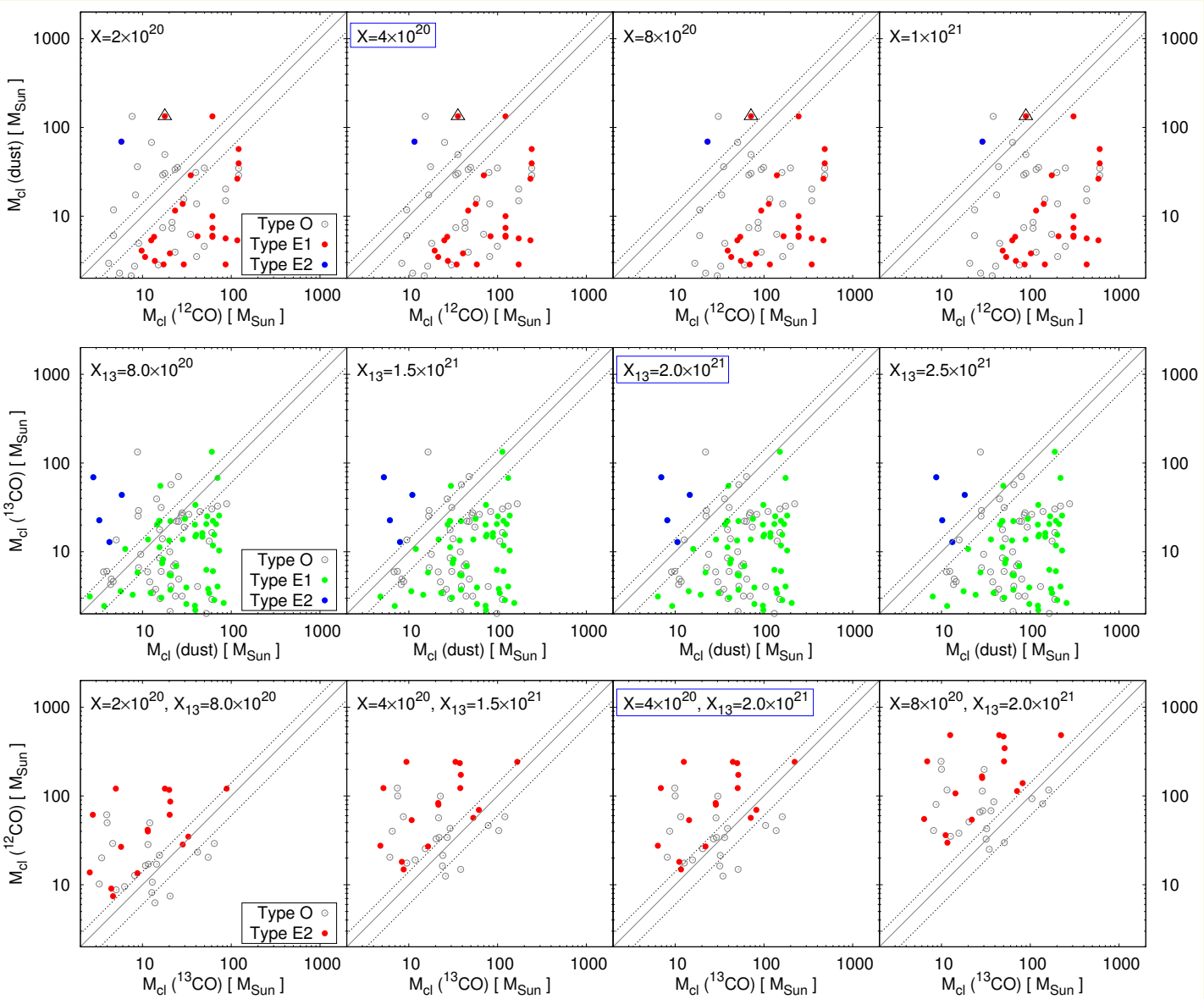
Clumps from CO and dust-emission maps of Rosette



red - ^{12}CO; green - ^{13}CO; blue - dust; Shades of grey: PACS and SPIRE (160, 250, 350 and 500 μm); dotted - excluded from consideration;

Tracer (Pop 1)	Nr. of clumps Total	Assoc.	Assoc. with (Pop 2)	Assoc. pairs	*Number ratios* E1/O	E2/O
^{13}CO	130	**98**	^{12}CO	37	0.00	0.76
^{13}CO	130	**133**	Dust	112	1.07	0.07
^{12}CO	68	**50**	Dust	63	0.80	0.03

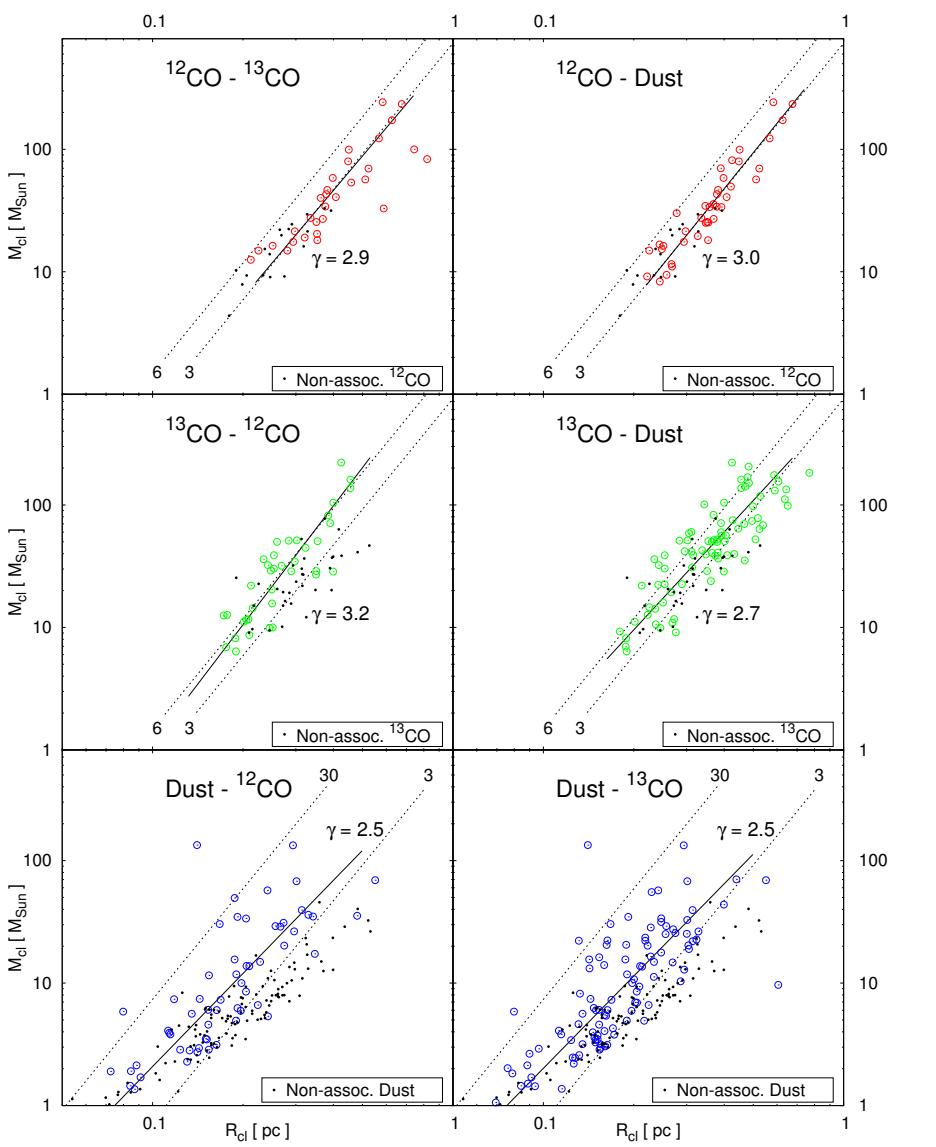
Estimation of the X-factor



$$X = \frac{N(\mathrm{H_2})}{W(\mathrm{CO})}$$
$[\mathrm{cm}^{-2}.\mathrm{K}^{-1}.\mathrm{km}^{-1}.\mathrm{s}]$

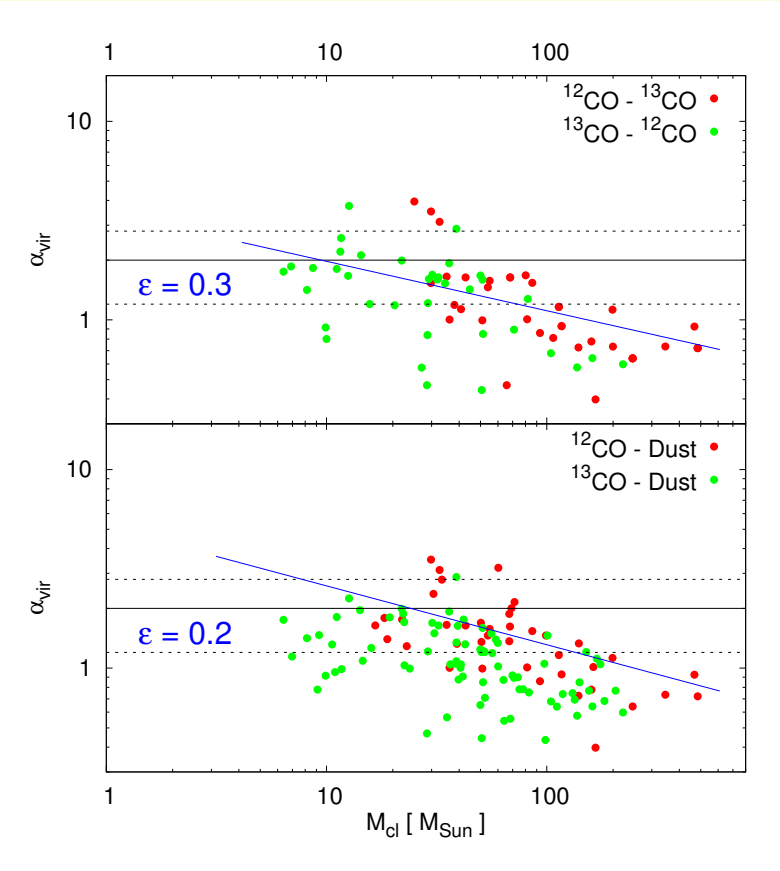
Dotted: mass uncertainties 40% (after Beaumont+ 2013)

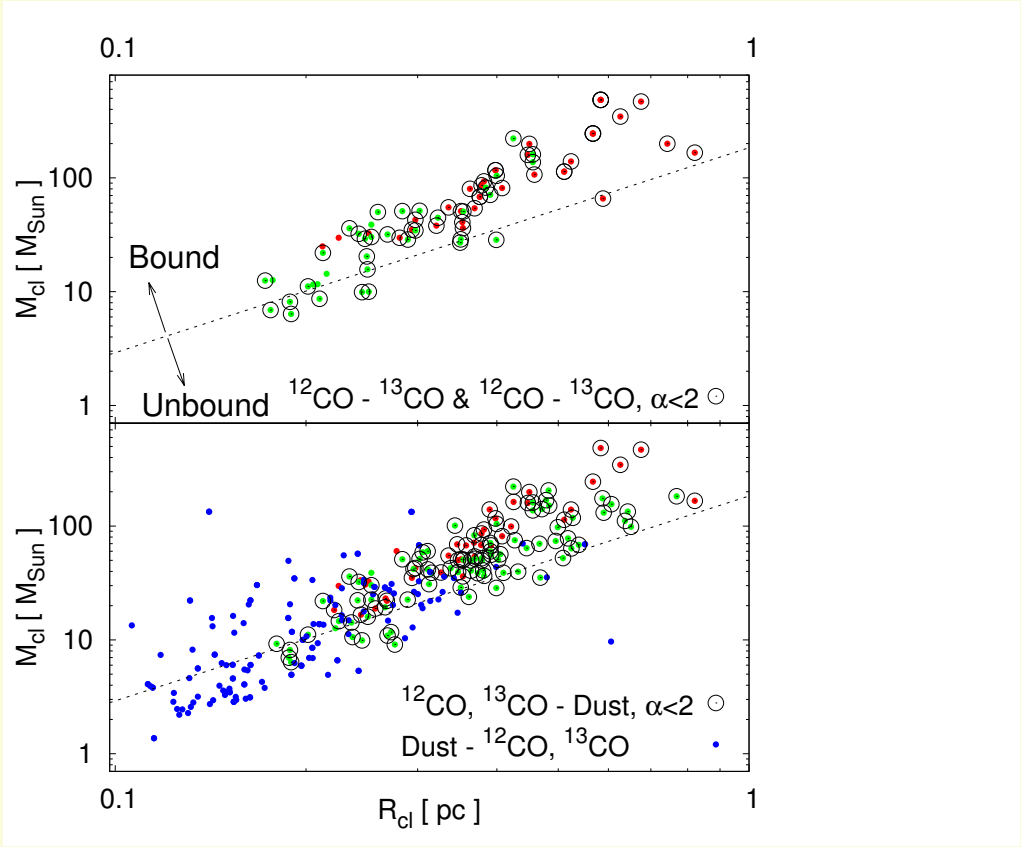
Size-mass relationships



Tracer	Total population	*Associated population*		
	γ	Tracer	Clumps	γ
^{12}CO	2.5 $\pm$ 0.3	^{13}CO	30	2.9 $\pm$ 0.2
		Dust	40	3.0 $\pm$ 0.2
		^{12}CO	17	3.0 $\pm$ 0.1
^{13}CO	2.6 $\pm$ 0.5	^{12}CO	37	3.2 $\pm$ 0.5
		Dust	80	2.7 $\pm$ 0.4
		^{13}CO	22	2.9 $\pm$ 0.2
Dust	2.3 $\pm$ 0.5	^{12}CO	58	2.5 $\pm$0.5
		^{13}CO	105	2.5 $\pm$0.6
		Dust	13	2.7 $\pm$0.7

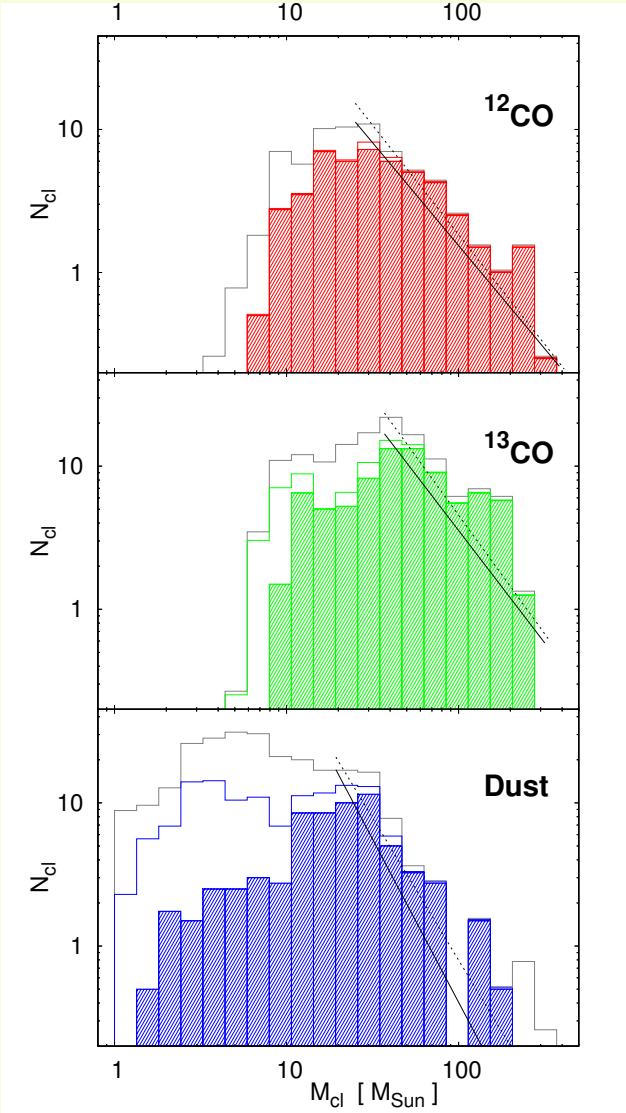
Virial analysis





Dotted line: locations of clump ensembles for $\alpha_{\rm vir} = 2$, $T = 15$ K and $\beta = 0.40$ from the model of Donkov, Veltchev & Klessen (2011, 2012).

Mass functions of Gaussian clumps



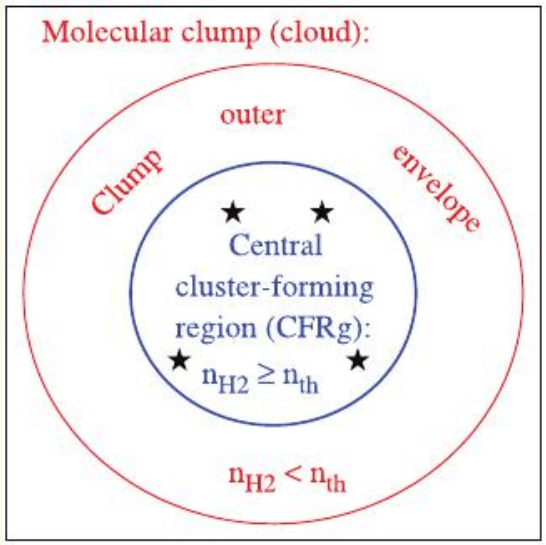
Tracer	All clumps				All associated clumps			
	ML			LSF	ML			LSF
	M_{ch}	D	$-\Gamma$	$-\Gamma$	M_{ch}	D	$-\Gamma$	$-\Gamma$
^{12}CO	29	0.09	1.5	1.2 ± 0.1	30	0.09	1.4	1.0 ± 0.2
^{13}CO	39	0.10	1.6	1.3 ± 0.2	40	0.12	1.6	1.1 ± 0.2
Dust	22	0.05	2.0	1.5 ± 0.2	25	0.07	2.3	2.3 ± 0.3

ML - Maximum Likelihood, D - KS statistic of ML-fit goodness;
LSF - Least-Squares Fit

Summary of the results

- The association of Gaussian clumps from CO and dust-emission maps allows for tracing the zones of current and future star formation in Rosette. Most of the associated clumps are assessed to be gravitationally bound and their location delineates the massive star-forming filaments.

- The associated Gaussian clumps extracted from CO tracers seem to obey a single mass-size relation $M_{\rm cl} \propto R_{\rm cl}^3$ implying approximately constant mean density. This behaviour could be explained by an ensemble of substructured star-forming clumps (Parmentier 2011) with typical density profile ($n(r) \propto r^{-2}$), developed under the influence of gravity. It is consistent with the derived mass functions with a nearly Salpeter slope ($\Gamma \sim -1.3$).



Summary of the results

- The associated Gaussian clumps extracted from dust-emission map differ from their CO associates by a shallower mass scaling (slopes about 2.5) and steeper mass functions ($\Gamma \simeq -2.3$). They trace dense parts of star-forming clumps at scales a few tenths of pc where no single mass-size relationship should be expected.