On the properties of fractal cloud complexes

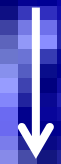
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IV Workshop "Estallidos", Madrid
(January 2004)

Introduction

- Goal: cloud structure → cloud properties



Fractal

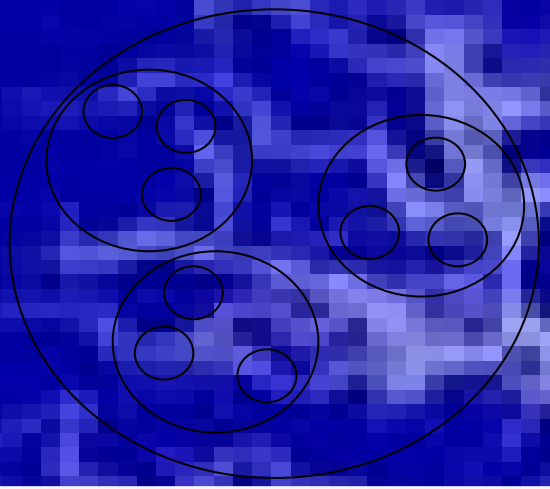
We can quantify the degree of “complexity” through the fractal dimension.

What is the fractal dimension of the ISM?

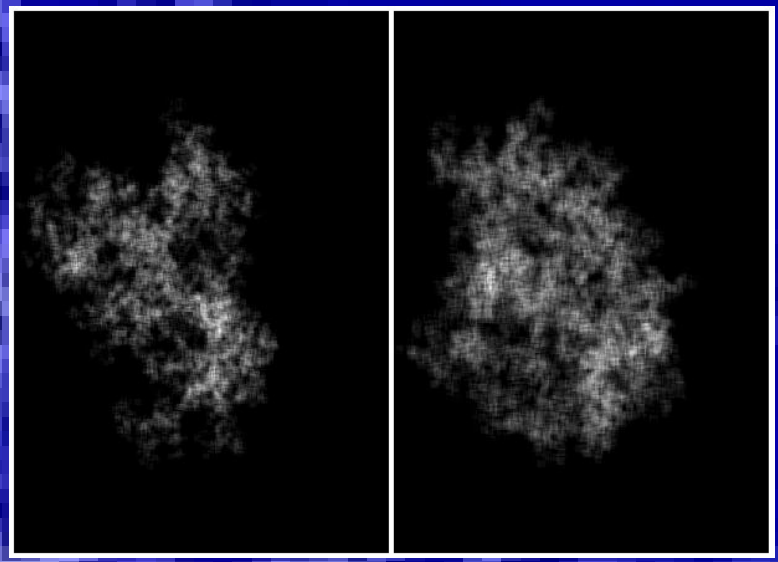
3rd workshop…

(Do you remember...? No? Don´t worry…)

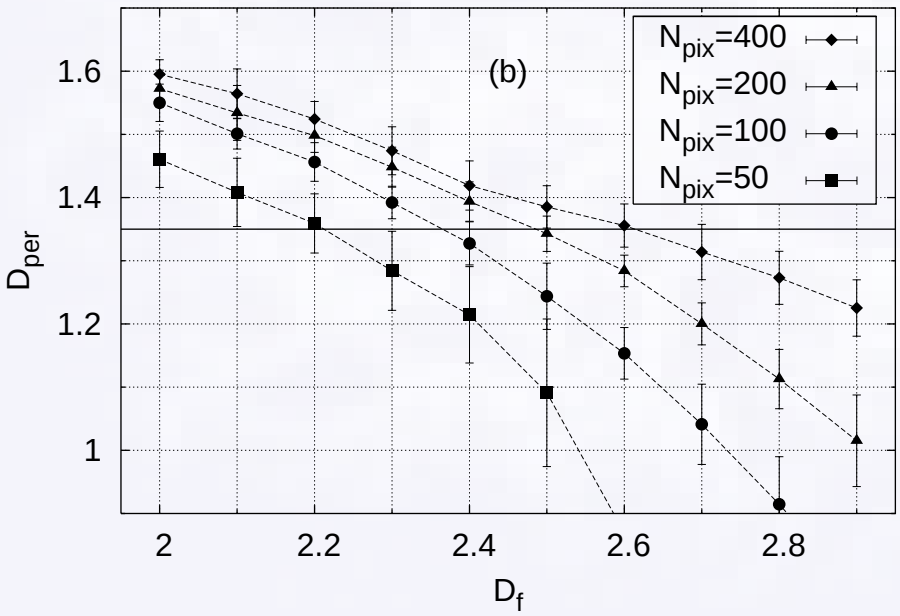
Reminder: Df is the (3D) fractal dimension and Dper is the (2D) perimeter-area based dimension. Smooth cloud → Df=3 and Dper=1. Dper(ISM) = 1.3-1.4



miprogramita.f



Df=2.3 Df=2.6

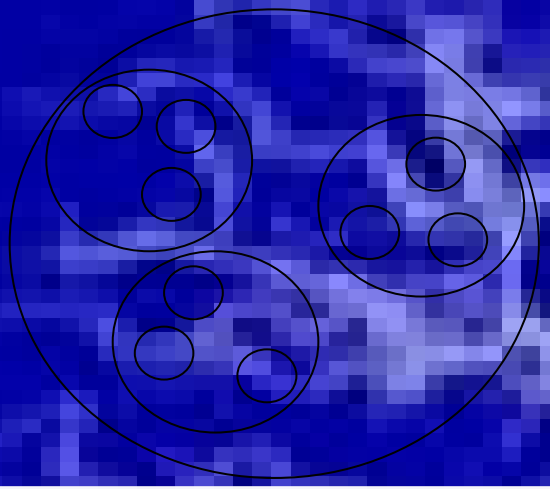


Df ≠ Dper + 1

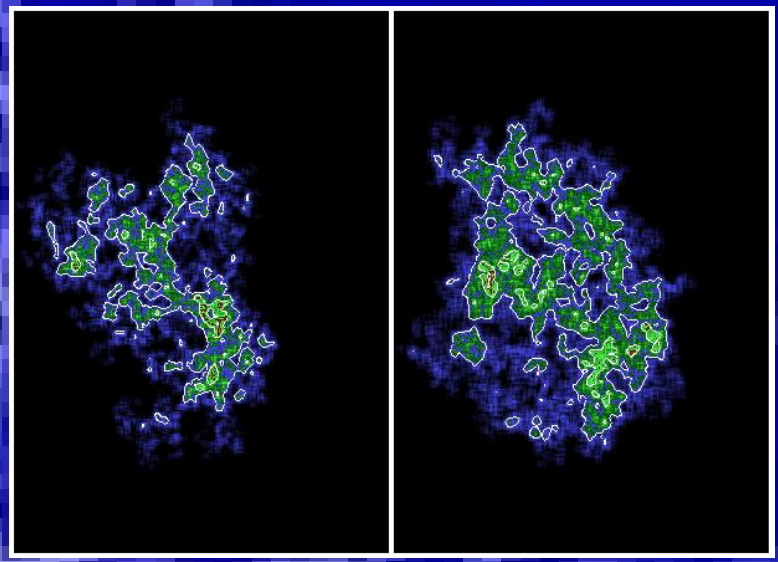
Df ≠ 2.3

Df is around 2.6 !!!

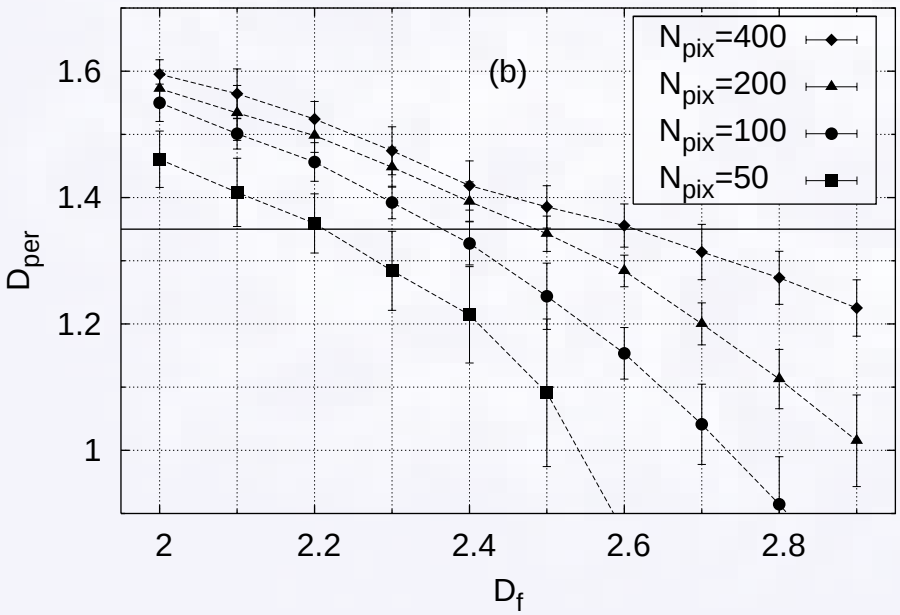
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Df=2.3 Df=2.6



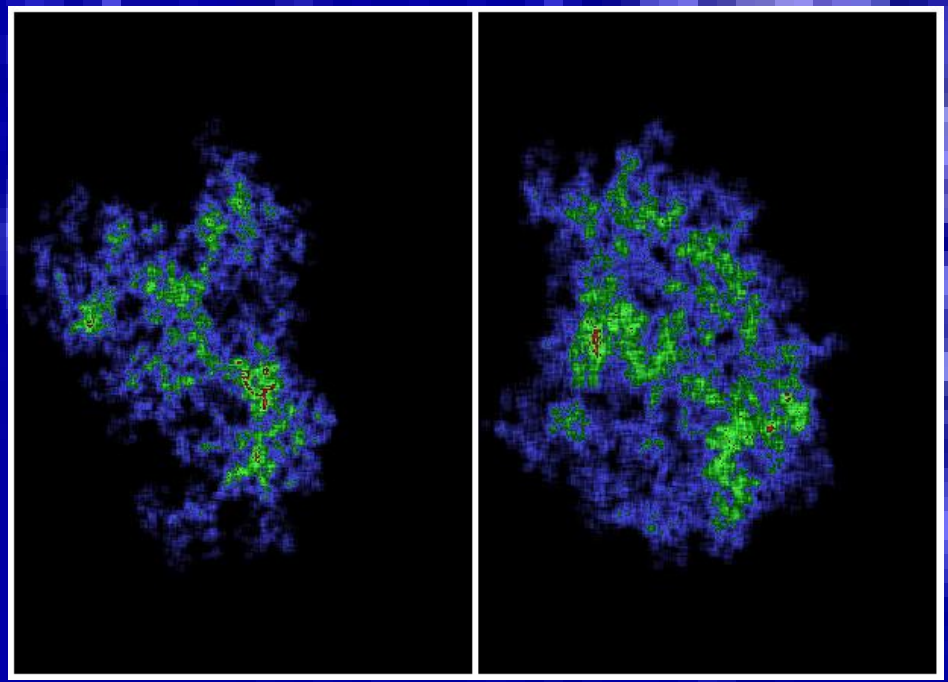
Df ≠ Dper + 1

Df ≠ 2.3

Df is around 2.6 !!!

This workshop:

- What is the relationship between the physical properties of the interstellar clouds and their fractal structure?
- Are the observed properties in agreement with relatively high fractal dimension values?



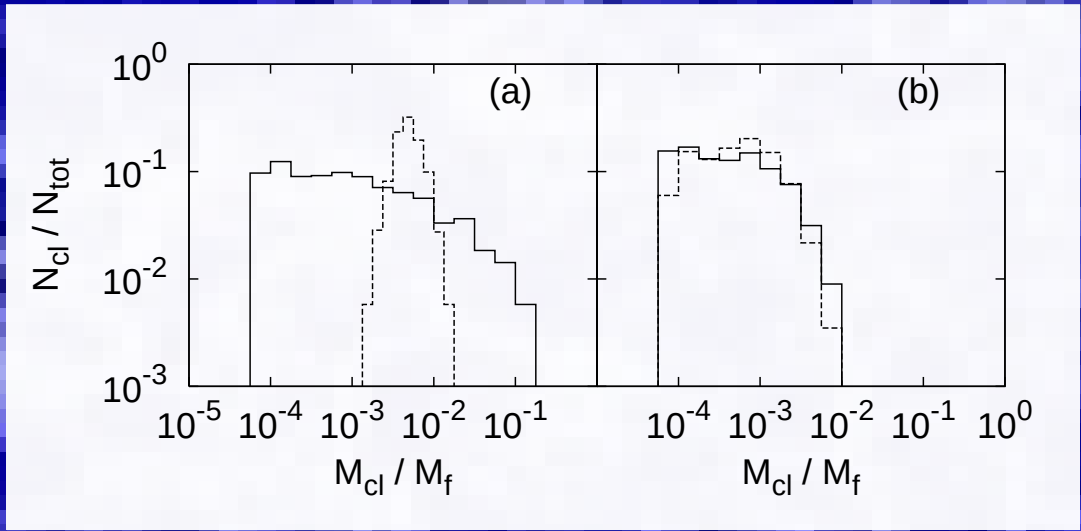
miotroprogramita.f:

- We place a grid over the fractal...
- We associate each peak in density with one "clump".
- Mcl: integrating the density field over the neighboring region, until some predefined threshold value (free parameter, ε).
- Rcl: cubic root of the volume.

Clump selection criterion

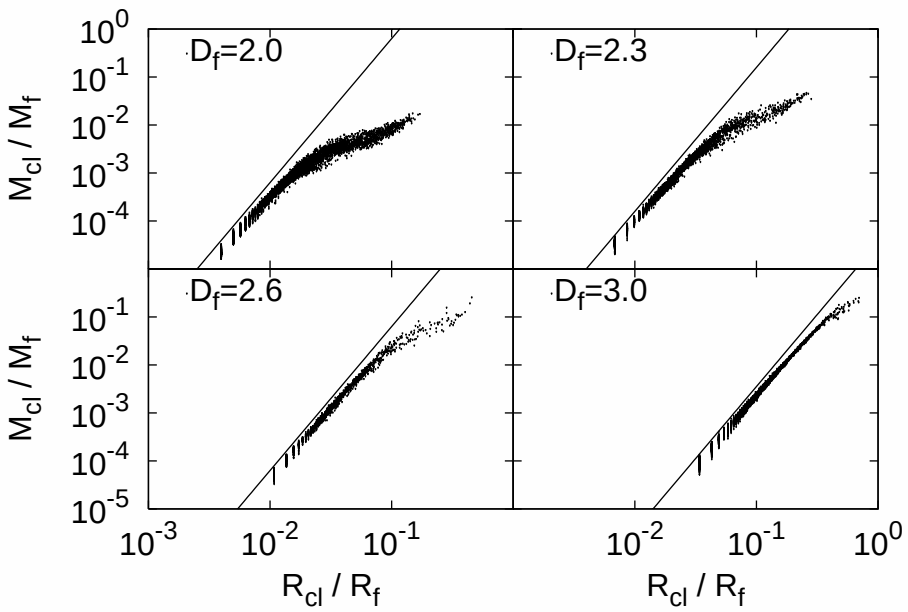
- We have to "decide" to which clump should be assigned the "ambiguous" pixels...

Geometric criterion: the closest (higher 1/d) [for example, CLUMPFIND]
Potential criterion: the highest "gravitational potential" (M/d) value
Others...



Df=2.6. Potential: solid line. Distance: dashed line.
(a) ε=1.0 and (b) ε=0.1 (ε = Mcl / Mf)

Mass vs size



Mass-radius relation. ε=1.0.
Solid line: constant density case.

Simple random sampling through the fractal yields slope = Df.

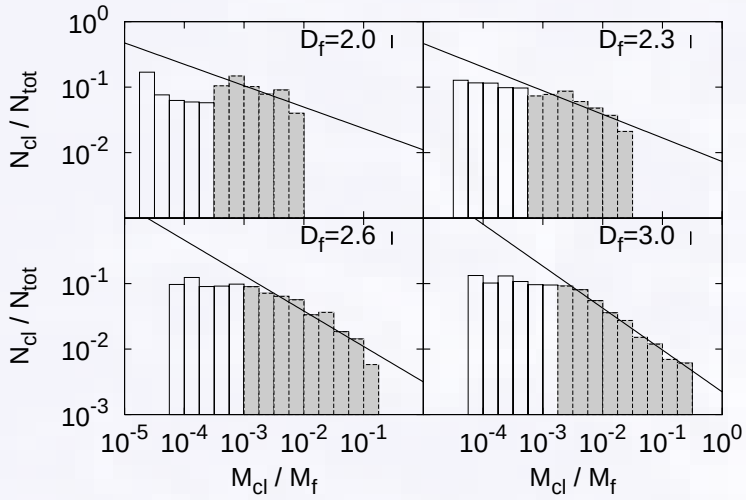
Comparison with observations (what a problem!!):
- different techniques and/or lines
- different clump identification methods
- different regions
- many studies show a weak (or scatter-dominated) correlation.

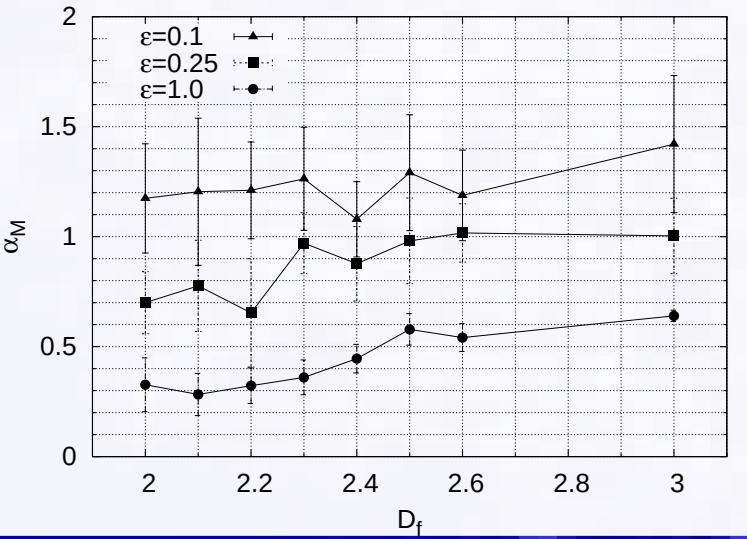
- slope ≈ 2 (Larson 1981)
- an artifact? (Scalo 1990)
- slope ≈ 2.3 (E&F96). OJO: Df=2.3??
- slope ≈ 2.4 - 3.7 (other authors)
- slope ≈ 1.5 - 2.1 (Reid & Wilson 05)

etc...

Falgarone et al. (2004) suggest an increase of Df as the size scale decreases (multifractality?)

Clump mass spectra



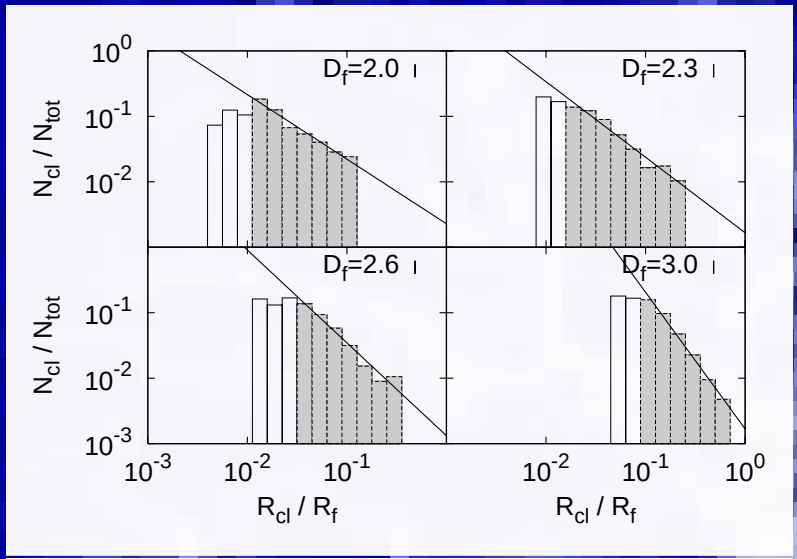


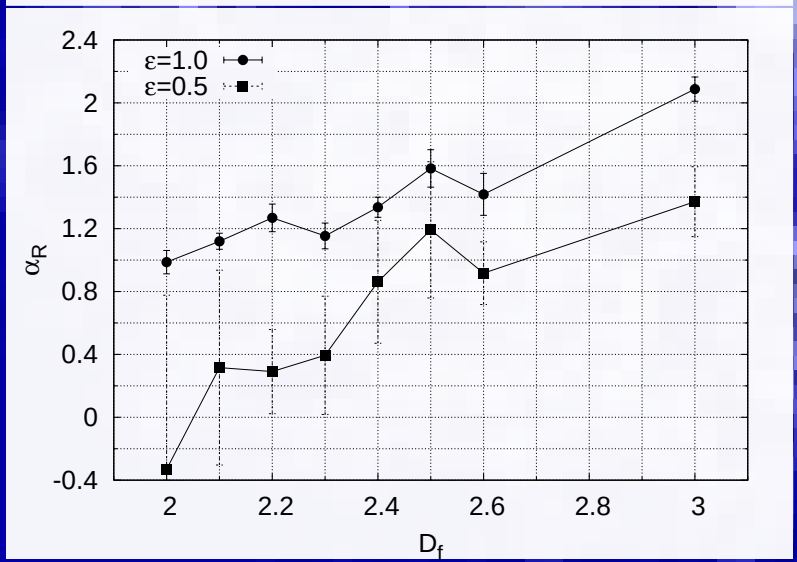
Simple random sampling through the fractal yields alpha_M = 1.

Observations (again a problem!!):
0.6 < alpha_M < 0.8 (E&F96)
0.3 < alpha_M < 1.1 (others)

If Df = 2.6 then alpha_M ≈ 0.55 for ε = 1.0
For ε = 0.1 we get alpha_M ≈ 1.2 +/- 0.2
(Salpeter = 1.35)

Clump size spectra





Simple random sampling through the fractal yields alpha_R = Df.

Observations (worst!!!!!):
clump sizes are quantities much more difficult to estimate in a robust manner.
alpha_R ≈ 2.3 (ojo: Df=?; E&F96)
1.8 < alpha_R < 2.4 (???)

If Df = 2.6 then alpha_R ≈ 1.4 for ε = 1.0
For ε = 0.5 we get alpha_R ≈ 0.9 +/- 0.2
(similar to HI clouds in LMC; Kim et al. 05)

Some general conclusions...

- Simple approach, i.e., "perfect" fractals: ISM properties as a function of Df (and ε).
- When ε ≈ 1 the properties are highly dependent on the clump definition criterion.
- Fractal clouds do not fulfill a simple power law for the mass-radius relation.
- Mass (size) spectra can be fitted to a power law in the range of relatively large masses (sizes).

and some not-so-general conclusions...

- Df ≈ 2.6 is roughly consistent with the "average" properties of the ISM.
- When ε decreases (from ~1 to ~0.1) alpha_M increases (from ~ 0.5 to ~1.2), suggesting this a likely link between the stellar IMF and the internal structure of GMCs.

For the future...

I think it is necessary a more *complete* and *systematic* study (both theoretical and observational).

Thanks....