Black hole entropy in LQG

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In coll. with many people: Agullo, Barbero, Corichi, Diaz-Polo, Villaseñor.

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The talk

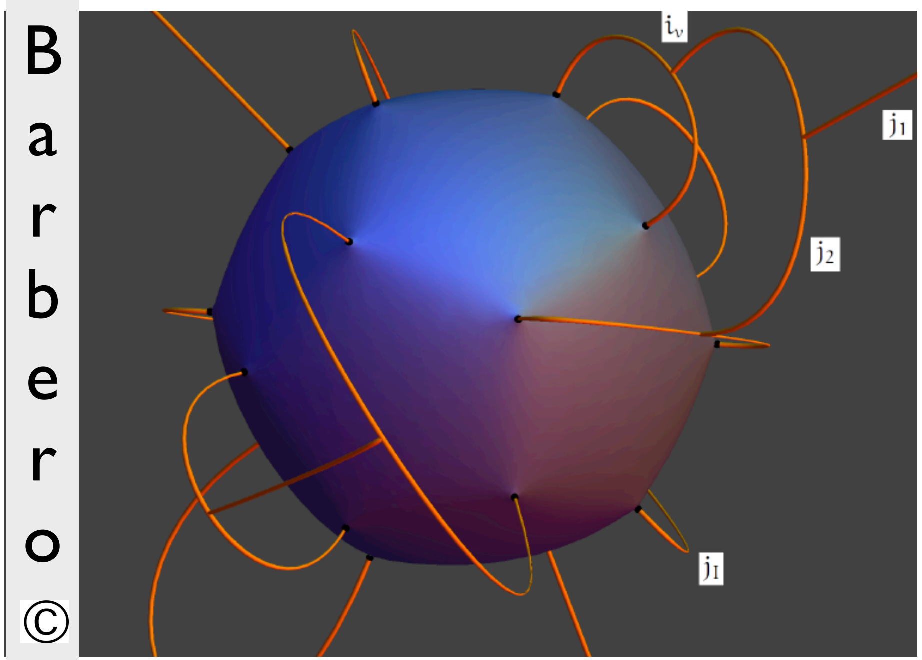
- Pictorical introduction.
- *Brute force* results.
- Number of states: Seeking the hidden order.
- The close future.

Pictorical introduction

1.- We work in the DL prescription (within the U(1) framework).
2.- We have a Hilbert space whose states can be writen as:

$$|(m_1, j_1, \ldots, m_n, j_n),\ \ the\ \ rest\ \ of\ \ the\ \ graph\rangle_V \otimes |(b_1, \ldots, b_n)\rangle_S$$

The entropy S of a quantum horizon of classical area a according to LQG and the ABCK framework is:



DLM- Class. Quantum Grav. 21 (2004) 5233
ABCK- *Phys. Rev. Lett*. 80(1998), 904-907

$$S = log\mathfrak{n}(a)$$

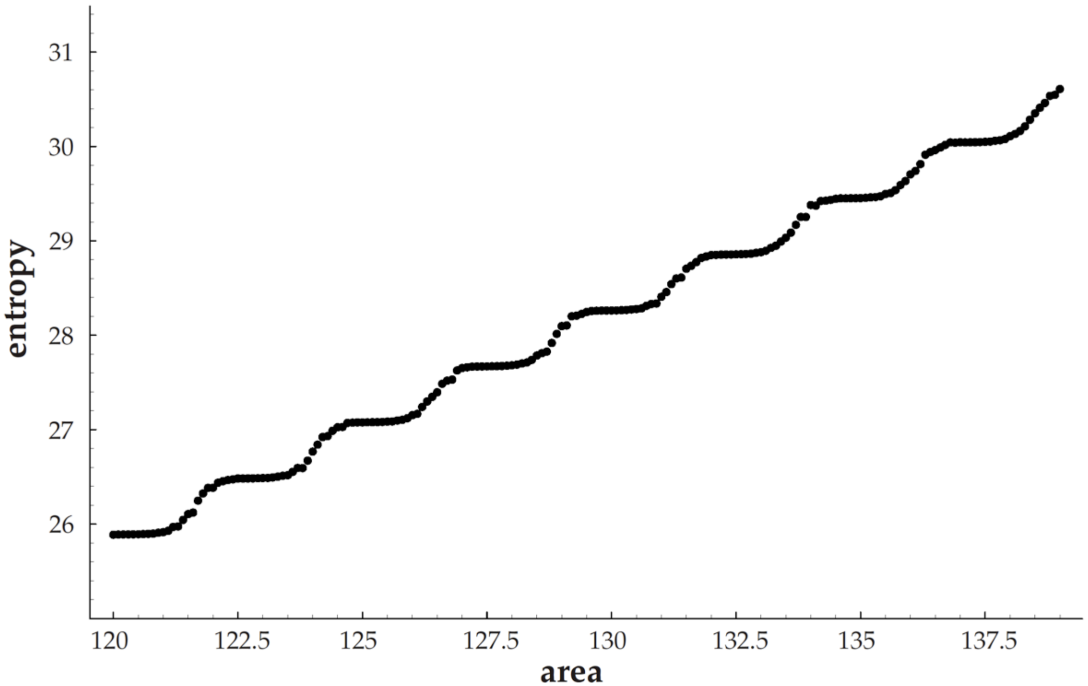
where $\mathfrak{n}(a)$ is 1 plus the number of all finite sequences $(m_1, \ldots, m_n)$ of non-zero elements of $(1/2)\mathbb{Z}$ such that the following equality and inequality are satisfied:

$$\sum_{i=1}^{n} m_i = 0 \qquad \sum_{i=1}^{n} \sqrt{|m_i|(|m_i|+1)} \leq \frac{a}{8\pi\gamma\ell_P^2}$$

Brute force results

Corichi, Diaz-Polo, EFB **Class.Quant.Grav. 24**:243-251,2007.
Corichi, Diaz-Polo, EFB **Phys.Rev.Lett. 98:**181301,2007.

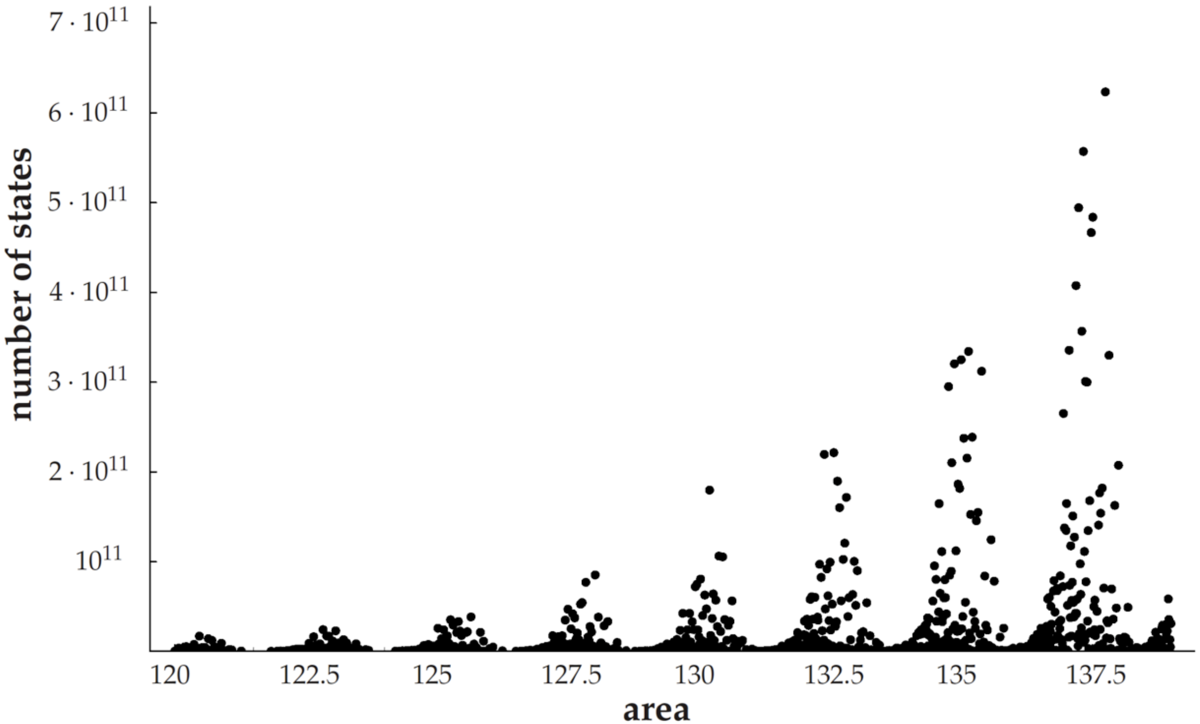
We can perform an <u>exact</u> counting making use of a computer. In this counting we select all the configurations which satisfy the DL conditions. This procedure give as the following behavior of entropy vs. area.



This method is really inefficient due to the huge amount of configurations which are computed. But, it reveals an interesting stair-like behavior of entropy as a function of the black hole horizon area.

Number of states: Seeking the hidden order

The origin of this stair-like function is rooted in the distribution of states in terms of area. These states are distributed in a “band structure”.



Number of states: Seeking the hidden order

Agullo, Diaz-Polo, EFB **Phys.Rev.D77:**104024,2008.

Surprisingly, the configurations contributing to the bands in the degeneracy spectrum can be labeled by a simple function of the spin labels at the punctures on the black hole horizon. In order to arrive to such function we define:

$$c = \{(k, N_k)\} \xrightarrow{|m_I| = k_I/2}$$ configuration (label on a puncture, number of punctures with that label).

$$K(c) = \sum_k k N_k \longrightarrow$$ Sum of all the labels in a given configuration.

$$N(c) = \sum_k N_k \longrightarrow$$ Total number of punctures in a given configuration.

$$P(c) := 3K(c) + 2N(c)$$

Each peak in the degeneracy spectrum is characterized by a single value of P(c)

Number of states: Seeking the hidden order

Agullo, Barbero, EFB, Diaz-Polo, Villaseñor **Detailed black hole state counting in LQG** (acepted in Phys. Rev. D)

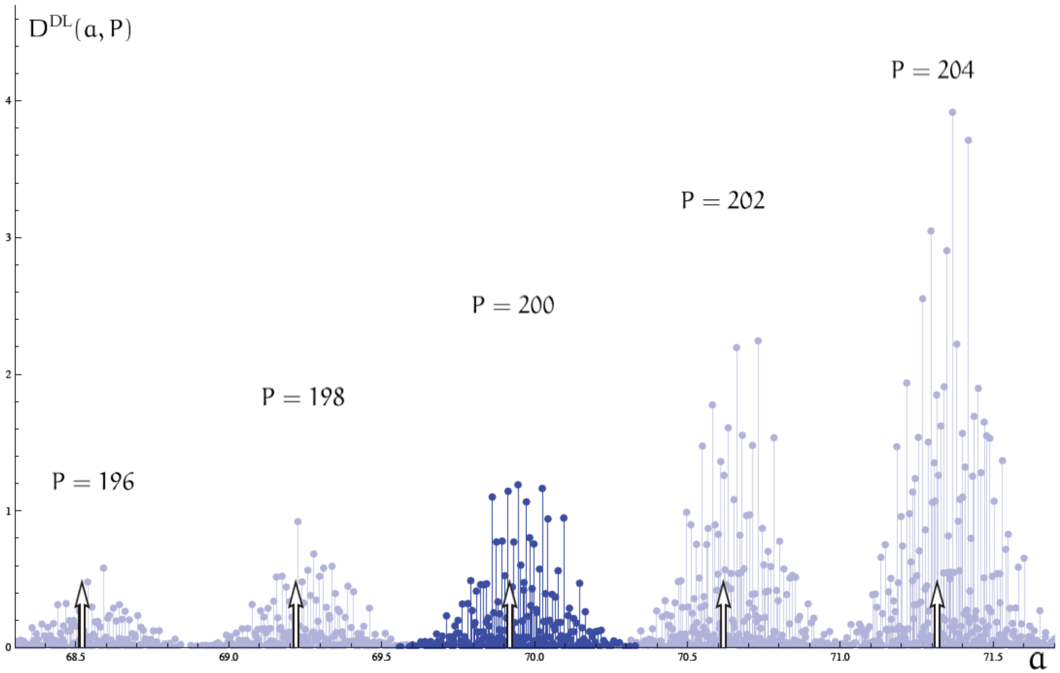
We can employ the generating function techniques in order to describe de states which correspond to a given value of P(c):

$$G^{DL}(\nu; z, x_1, x_2, \dots) = \left(1 - \sum_{i=1}^{\infty}\sum_{\alpha=1}^{\infty} \nu^{3k_\alpha^i+2}(z^{k_\alpha^i} + z^{-k_\alpha^i})x_i^{y_\alpha^i}\right)^{-1}$$

$$D^{DL}(a, P)$$

We have under control all the analytical properties of the bands.

This is the fundamental ingredient needed to get the asymptotic limit behavior.



The close future

1.- Thanks to the techniques related with number theory and generating functions, right now we are in a position to study the asymptotic limit of the degeneracy spectrum.

2.- Once computed such limit we have to confirm if the astrophysical black holes are in that limit or not.

3.- With all those analytical results at hand we will study the black hole spectroscopy within this framework.

Gracias
Thanks