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Explorando el Modelo de Ising: Simulaciones Montecarlo en 2D y 3D

Presentado por:
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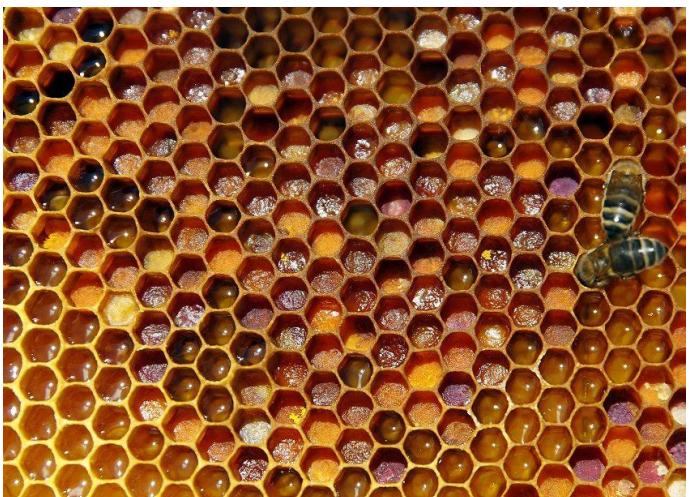
- **Contenido**

- Modelo de Ising.
- Análisis modelo Ising 2D y transiciones de fase .
- Aproximación 3D.

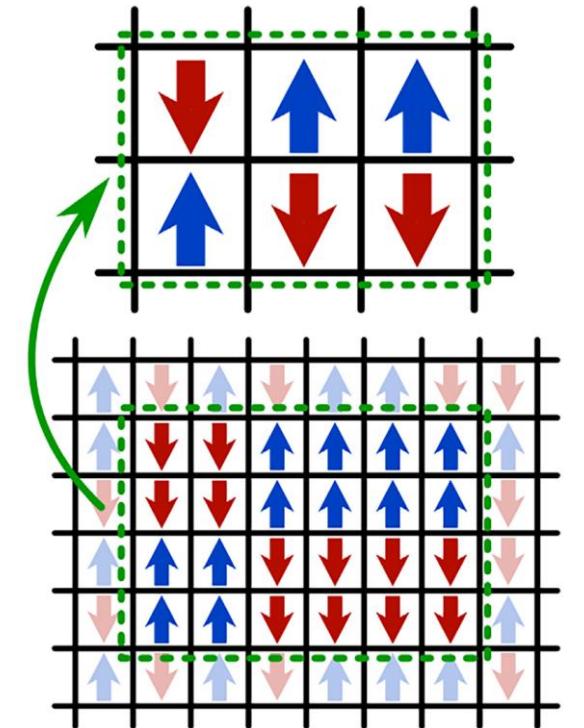


• Modelo de Ising

Es un modelo clásico de la física estadística que describe sistemas de espines en una red. Cada espín puede tomar dos valores (+1 o -1) y puede interactuar con sus vecinos. Este modelo es clave para entender transiciones de fase.



$$\mathcal{H} = -J \sum_{\langle i,j \rangle} \sigma_i \sigma_j - h \sum_i \sigma_i$$



• Modelo de Ising

El sistema evoluciona hacia configuraciones con menor energía según la estadística de **Boltzmann**:

$$P(S) = \frac{e^{-H/K_B T}}{Z}$$

$$M = \sum_i \sigma_i$$

$$C_v = \frac{1}{k_B T^2} (\langle E^2 \rangle - \langle E \rangle^2)$$

Unidades adimensionales.

$$K_B = 1$$

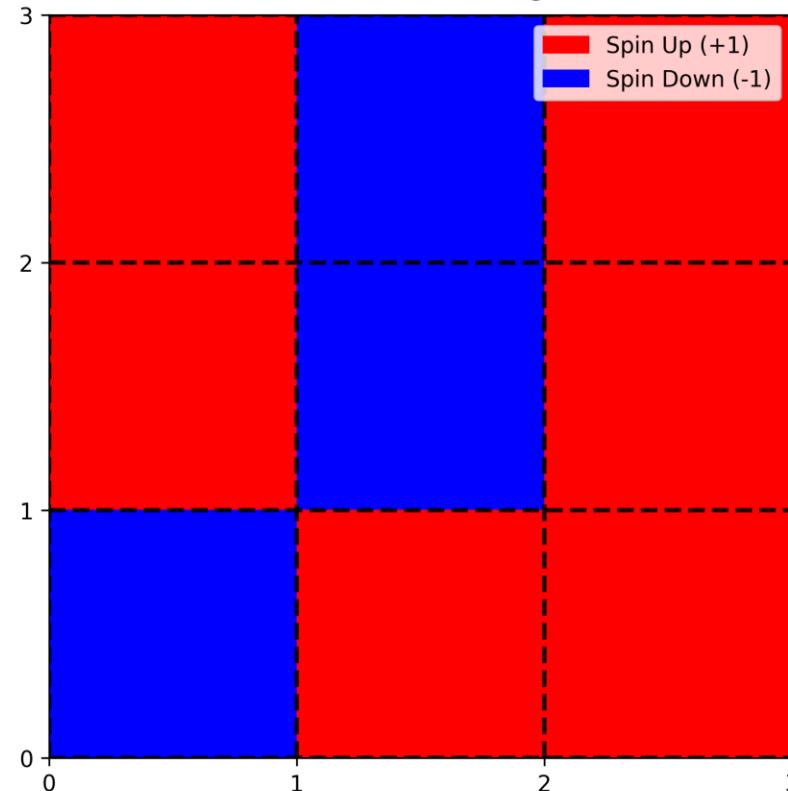
Solo para ($J = 1$) – Sistemas ferromagnéticos.

$$\chi = \frac{1}{k_B T} (\langle M^2 \rangle - \langle M \rangle^2)$$

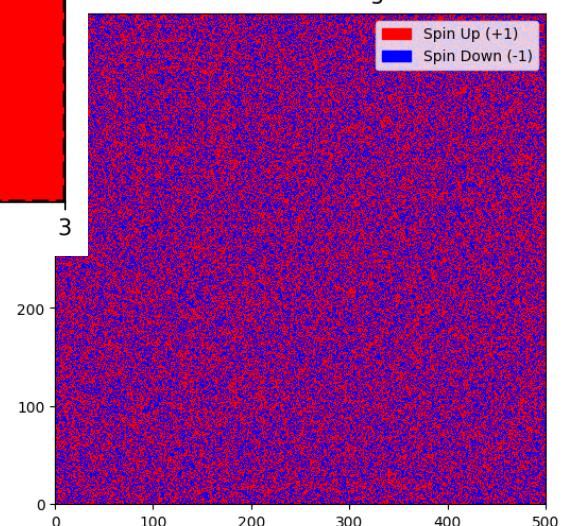


• Modelo básico 2D ($h = 0$)

Random Initial Configuration



Random Initial Configuration



Condiciones
de frontera:

- Periódicas
- No periódicas

Configuración
inicial:

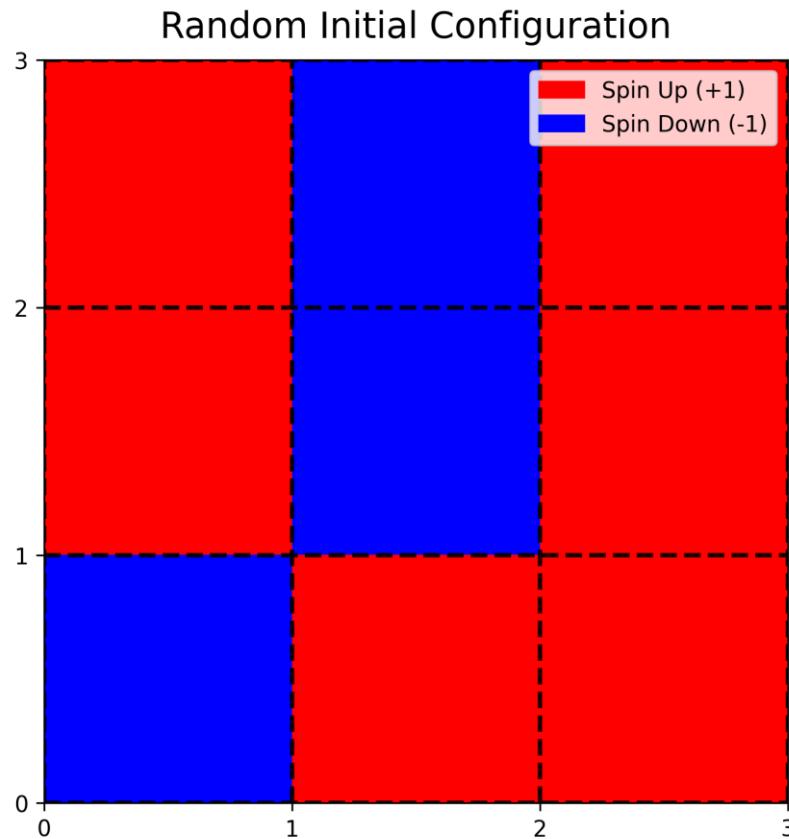
- Aleatorio
- Ordenado

Temperatura:

- $T = 1.0$
- $T = 2.269$
- $T = 8$



• Algoritmo de metrópolis

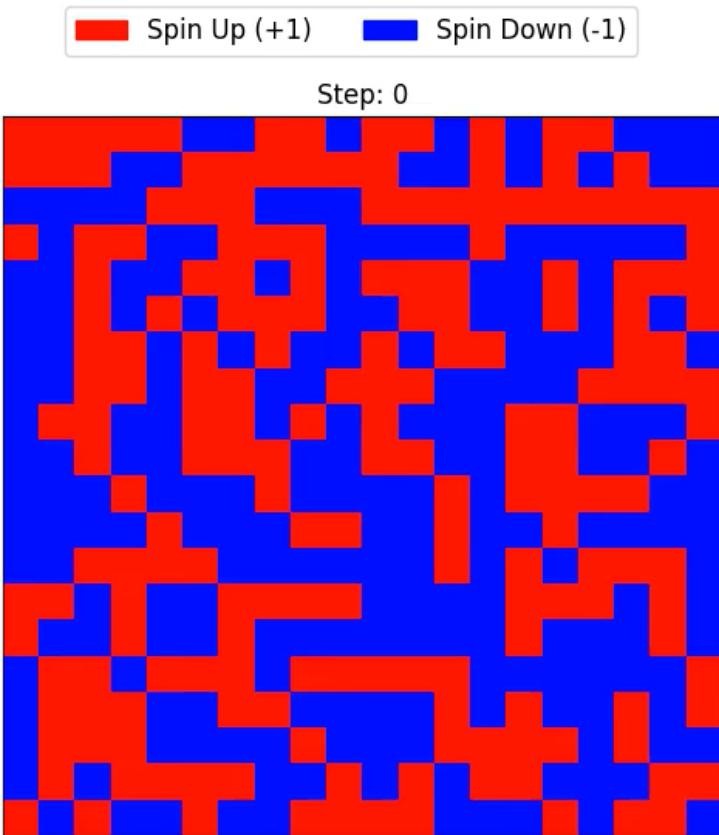


- Seleccionar un espín al azar.
- Calcular la variación de energía ΔE al invertir el espín.
- generar un número aleatorio r entre $[0, 1]$
- Si $r < e^{-\beta\Delta E}$ aceptar el cambio.
- Si el cambio es aceptado, actualizar el espín y la energía.
- Repetir hasta n iteraciones.

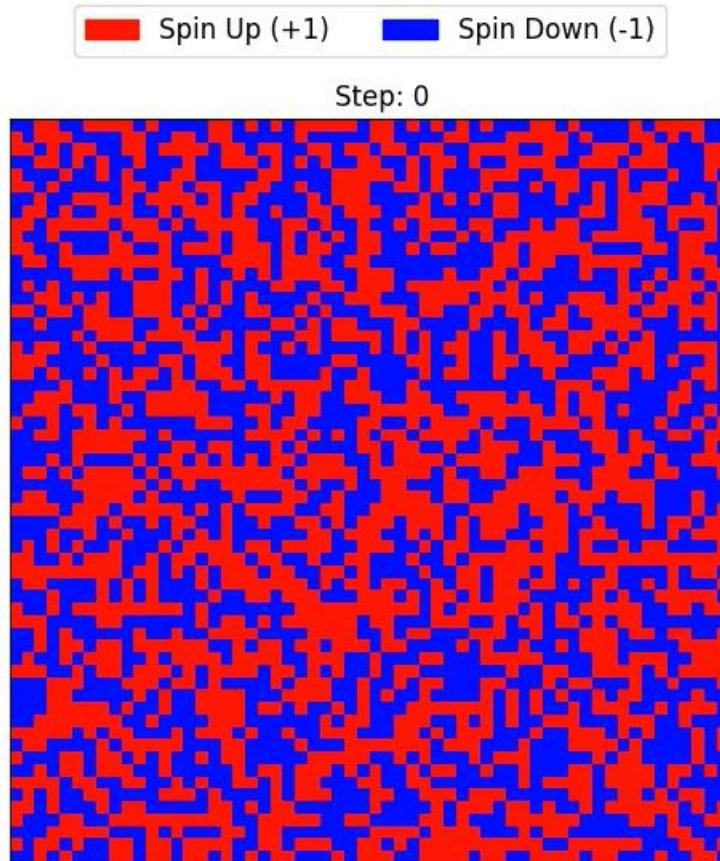


• Evolución del sistema

Spin Configurations at $T = 1.00$, $L = 20$

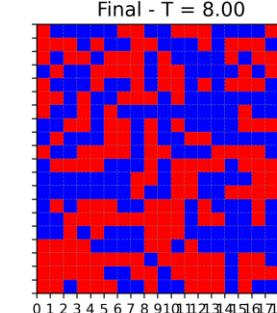
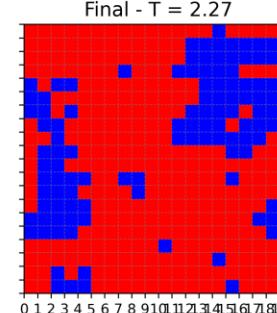
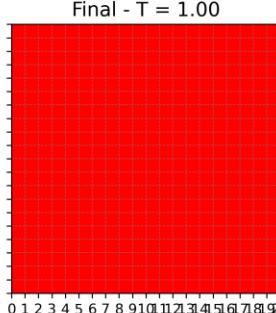
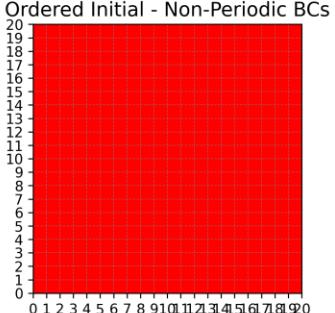
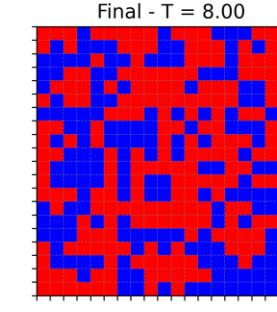
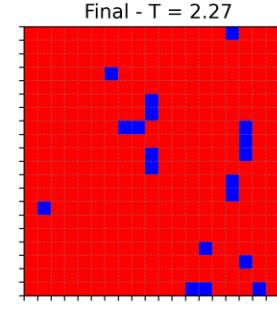
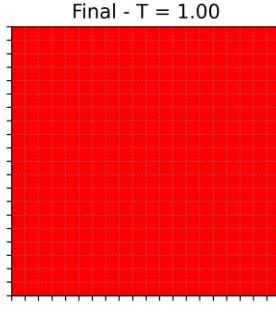
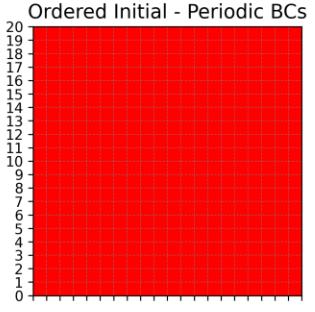
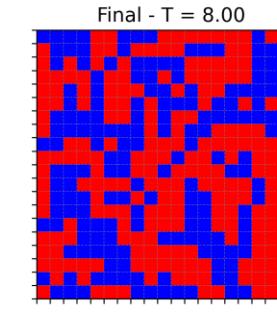
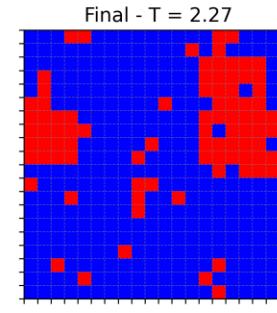
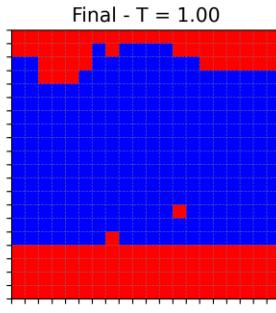
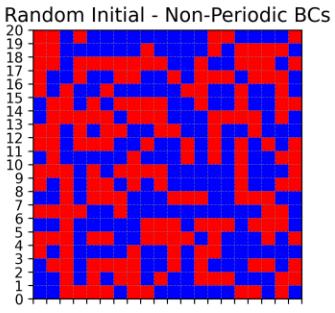
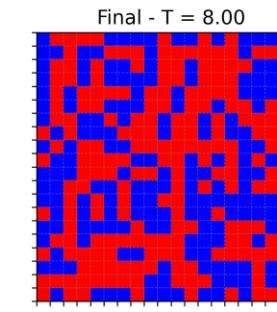
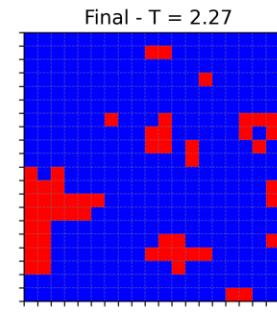
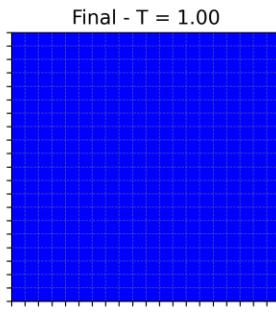
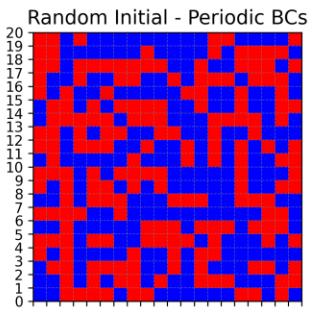


Spin Configurations at $T = 1.00$, $L = 60$



Spin Configurations at Different Temperatures ($L = 20$)

■ Spin Up (+1) ■ Spin Down (-1)

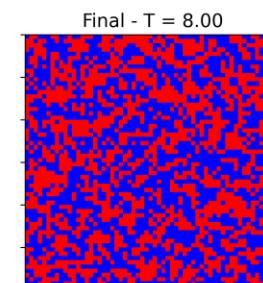
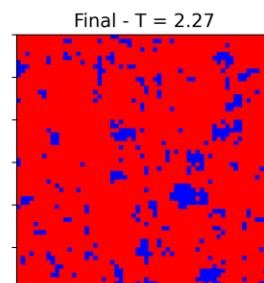
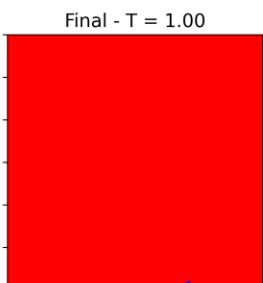
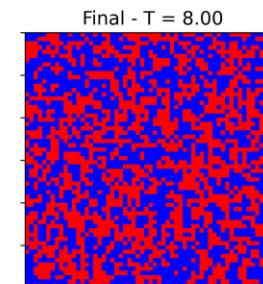
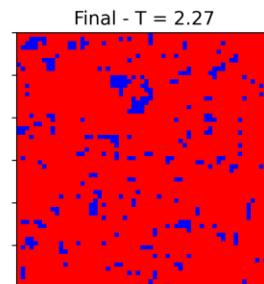
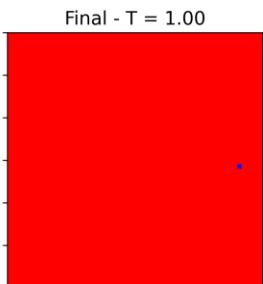
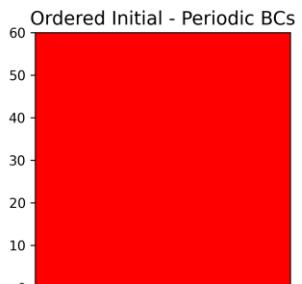
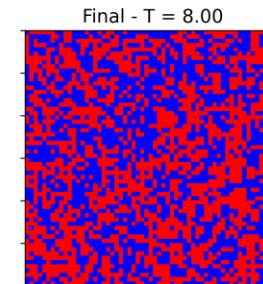
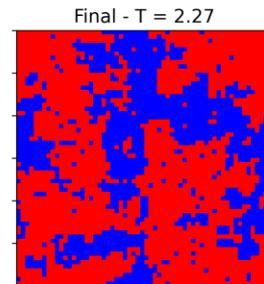
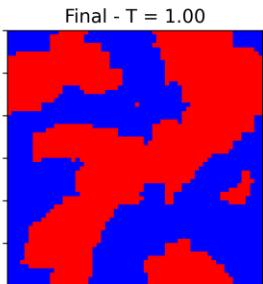
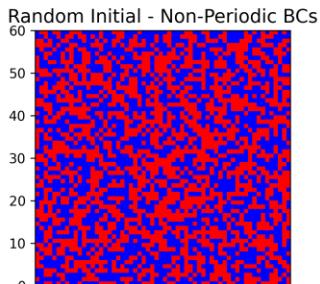
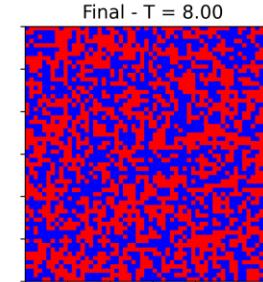
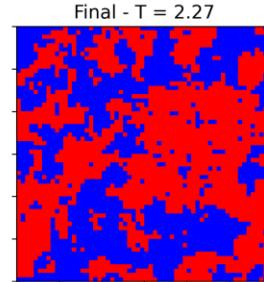
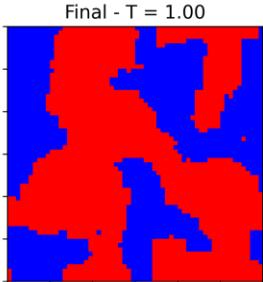
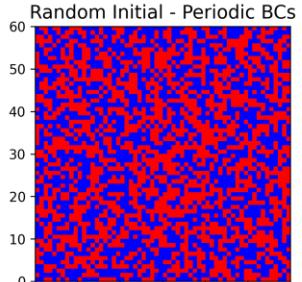


Resultados $L = 20$



Spin Configurations at Different Temperatures ($L = 60$)

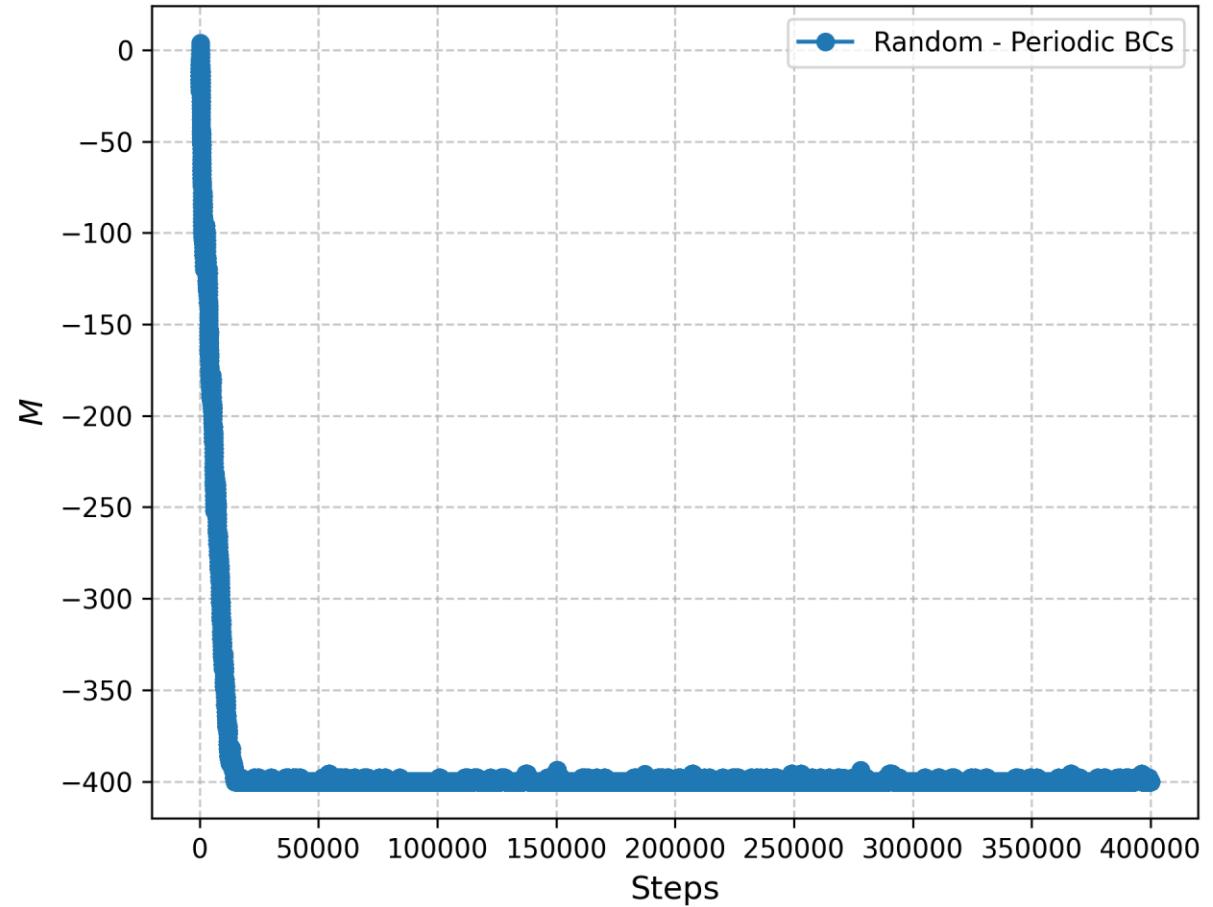
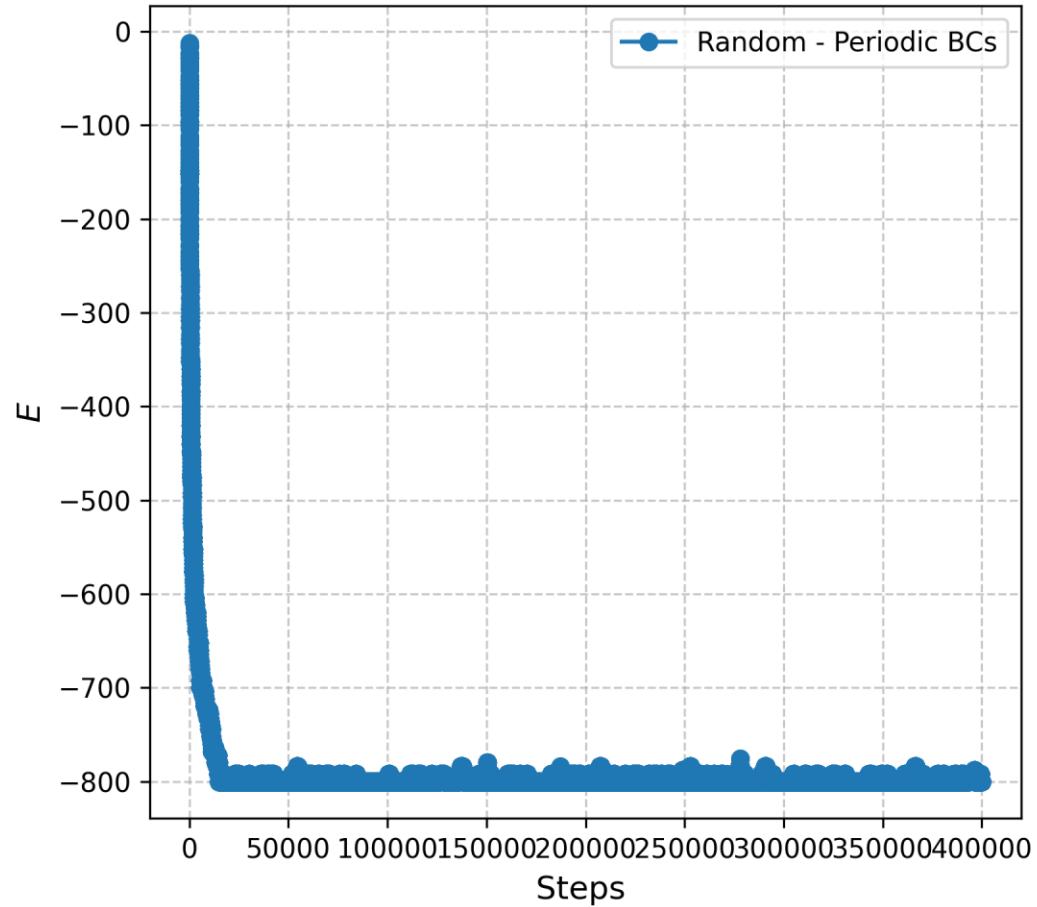
Legend: Spin Up (+1) [Red] Spin Down (-1) [Blue]



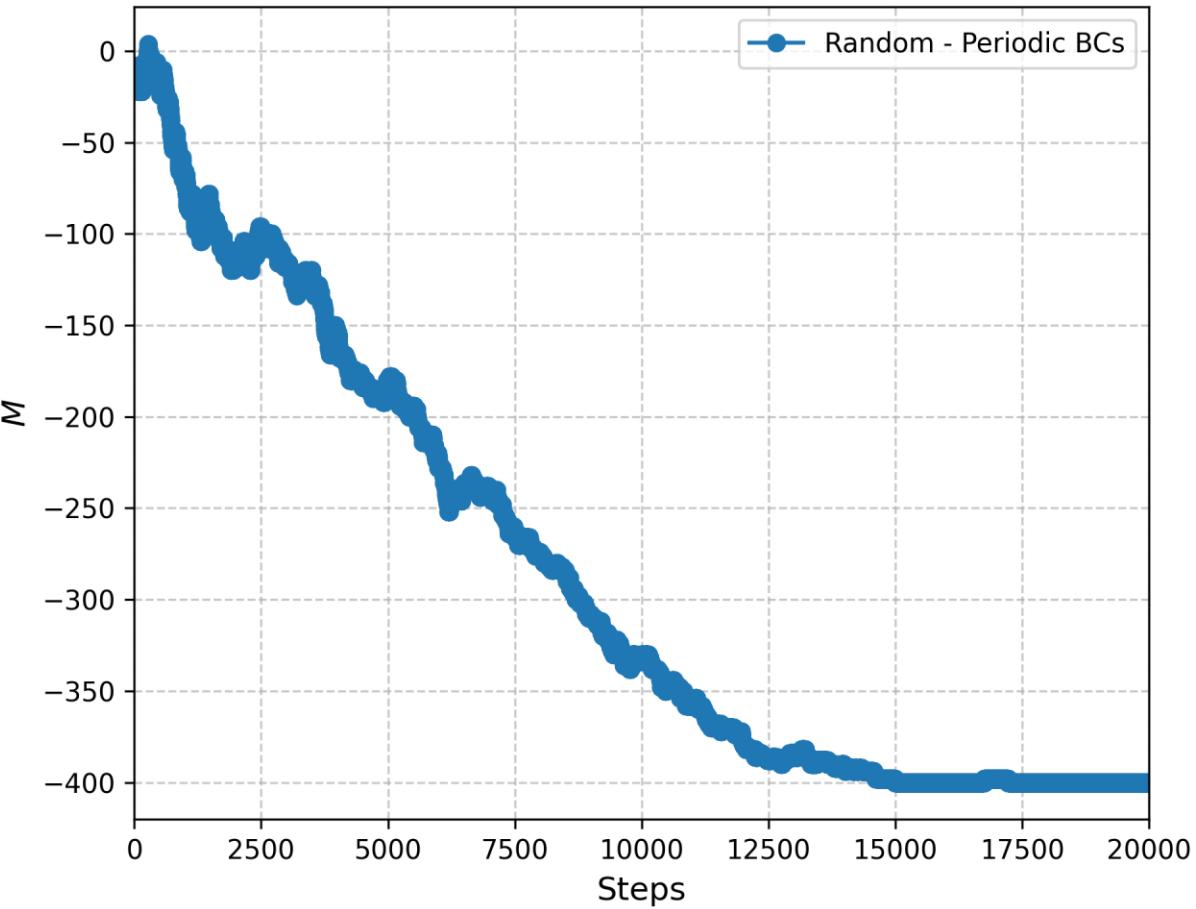
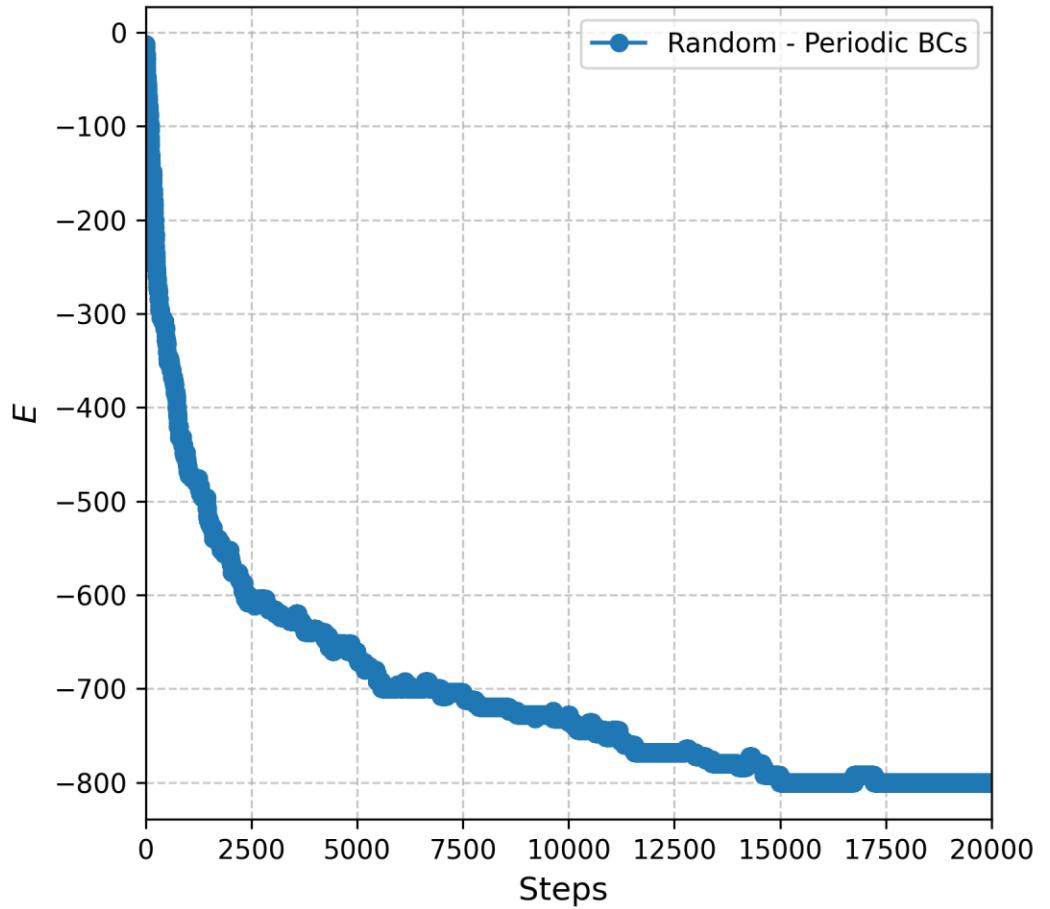
Resultados $L = 60$



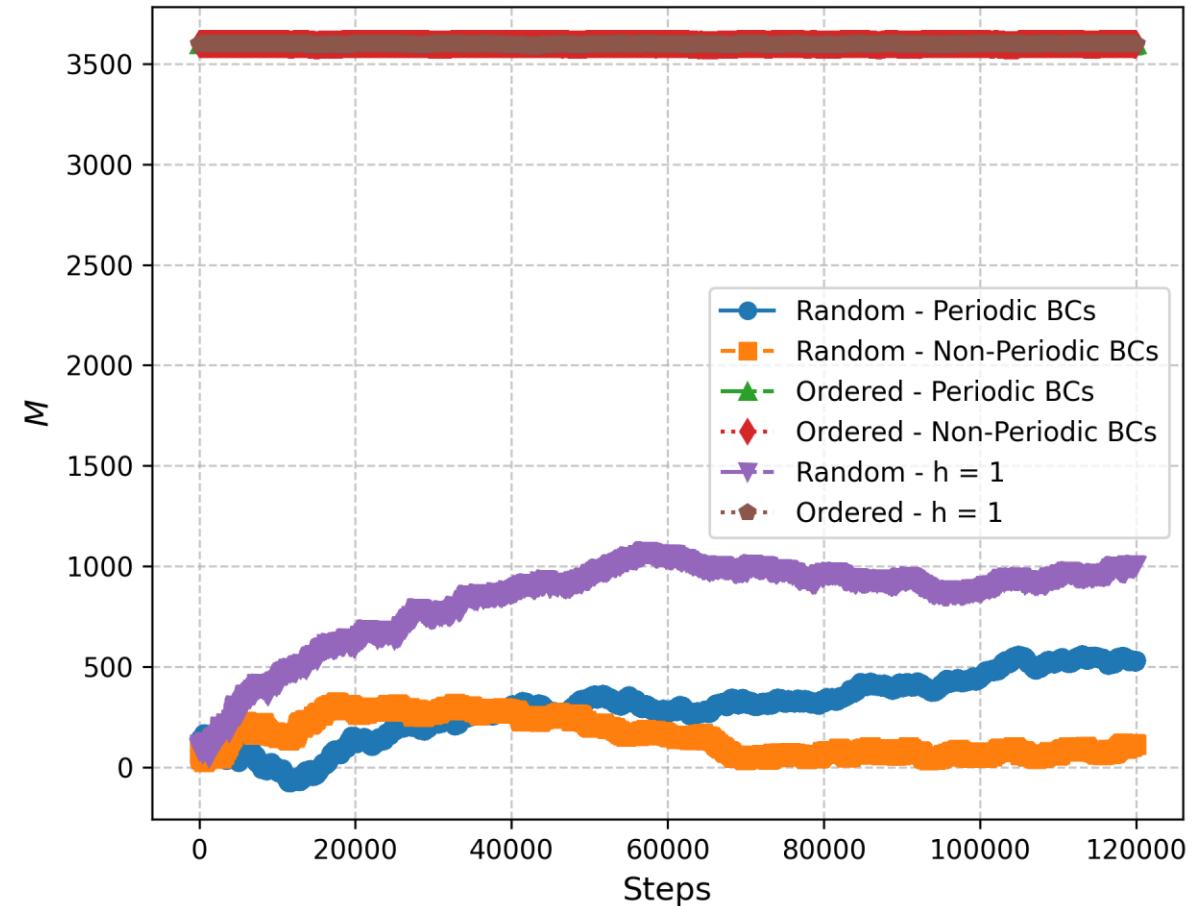
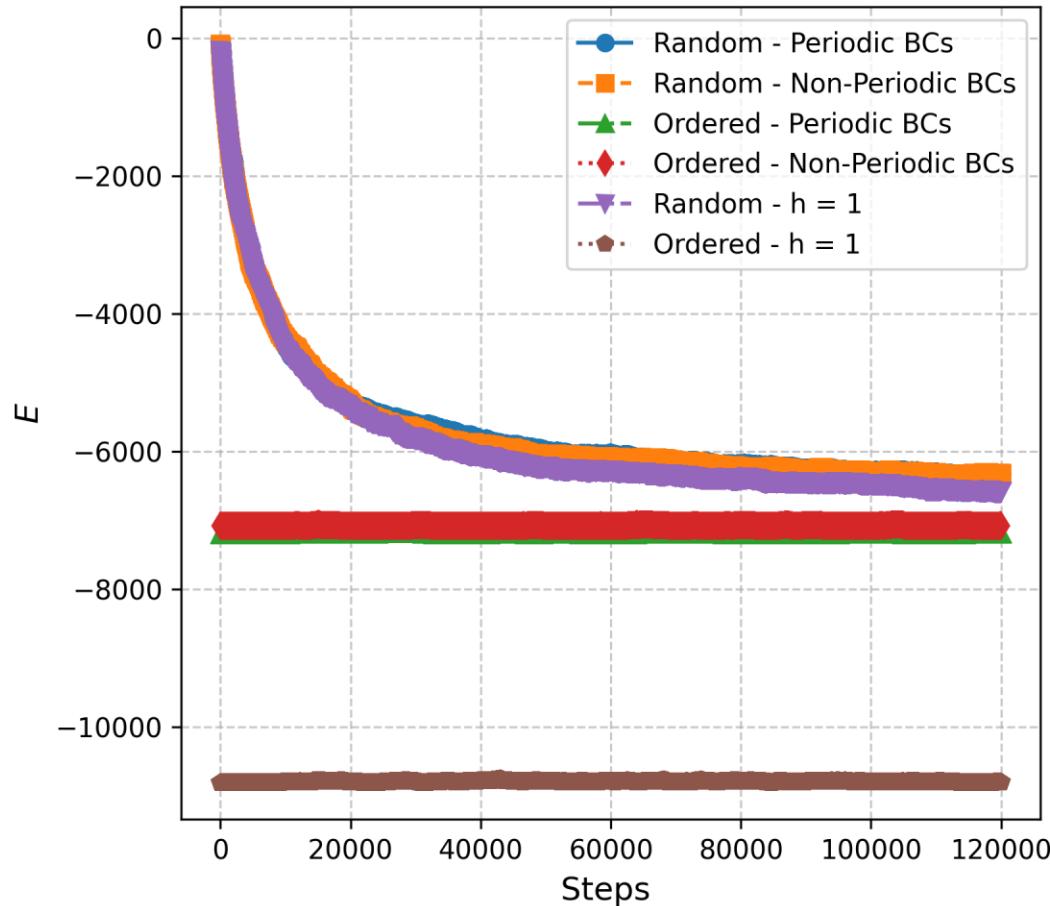
• ¿Cuántos pasos se dan?



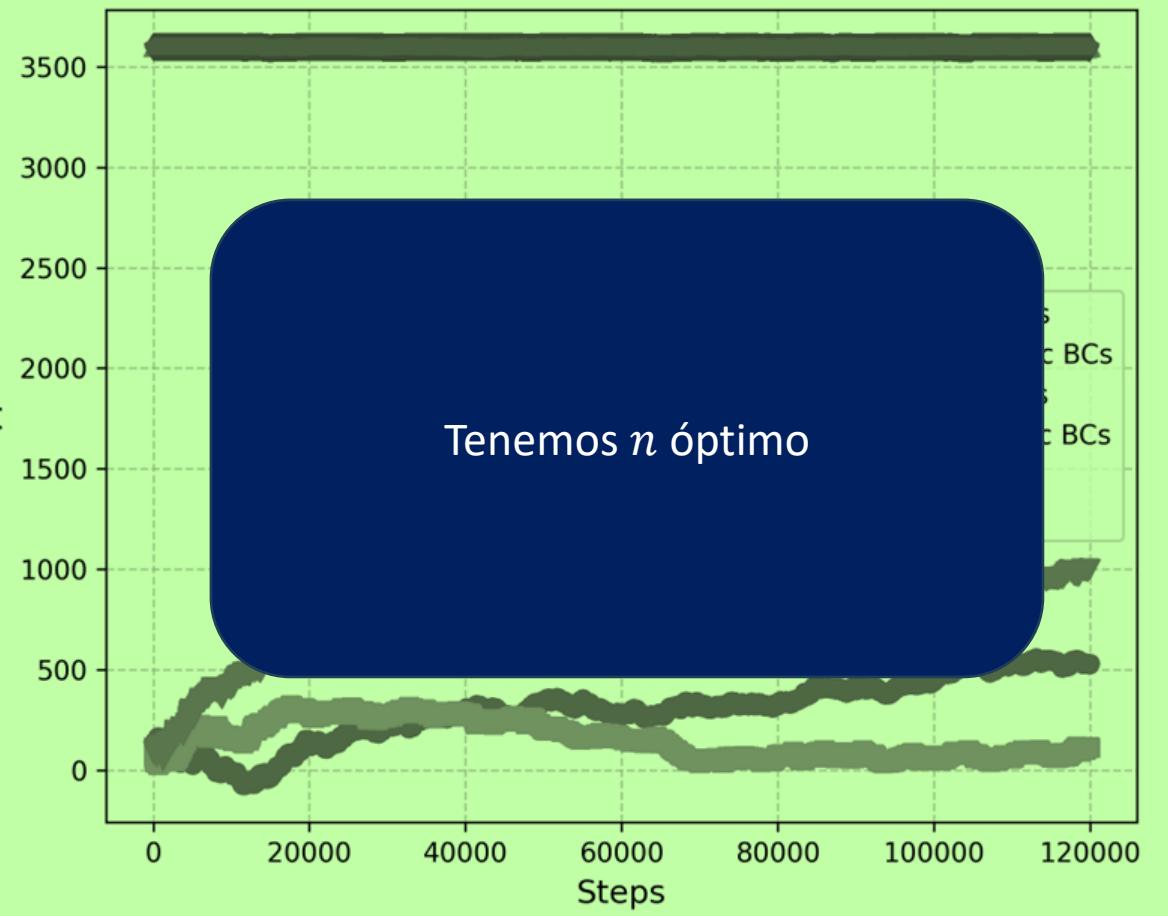
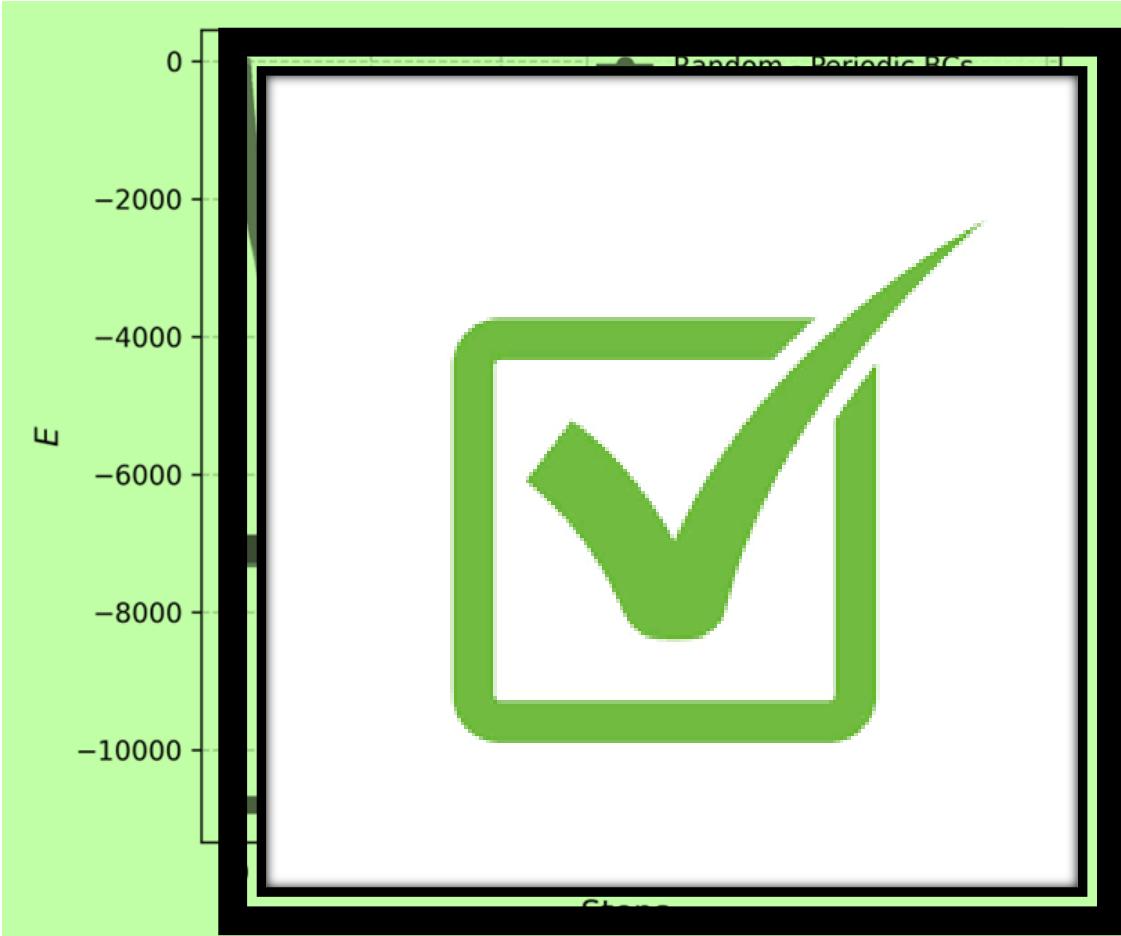
• Analizamos los pasos



• Analizamos los pasos ($L = 60$)



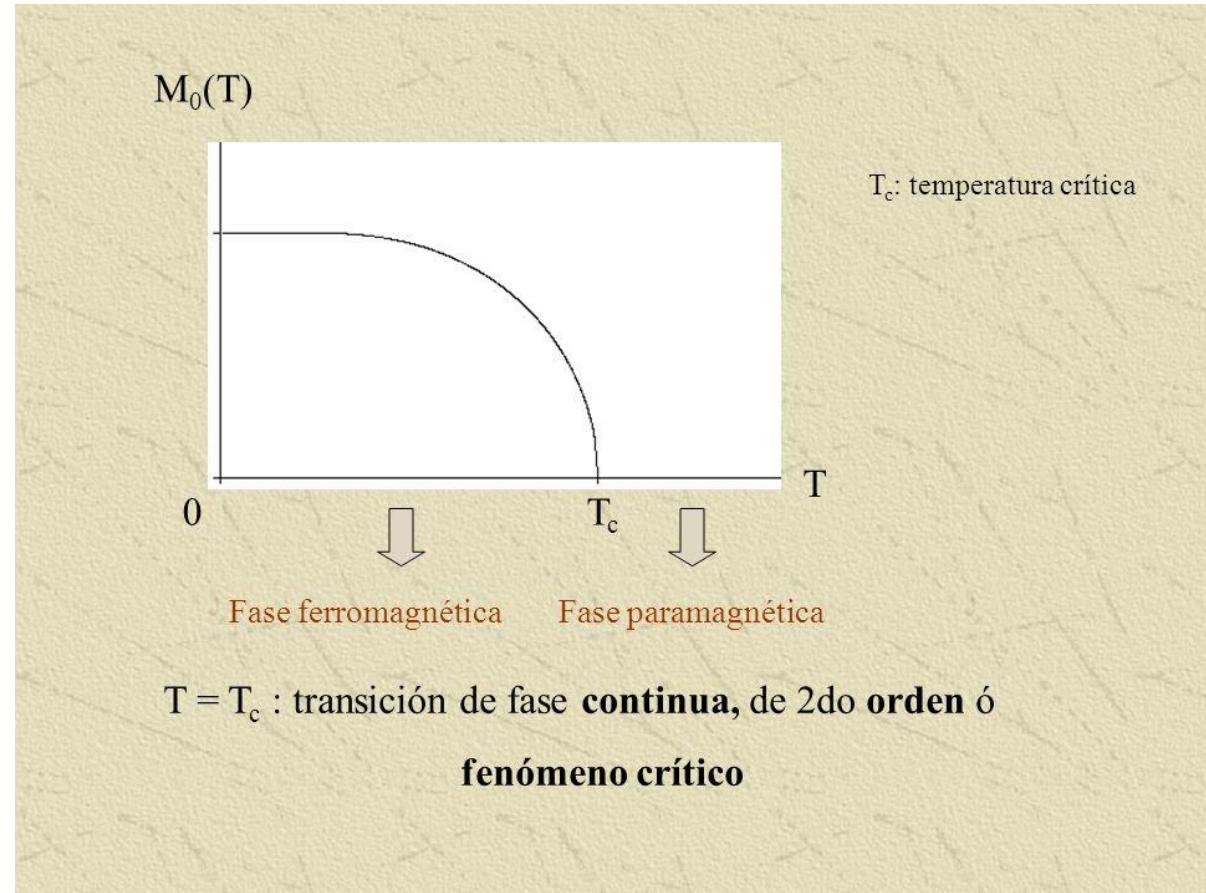
- Analizamos los pasos ($L = 60$)



• Transición de fase

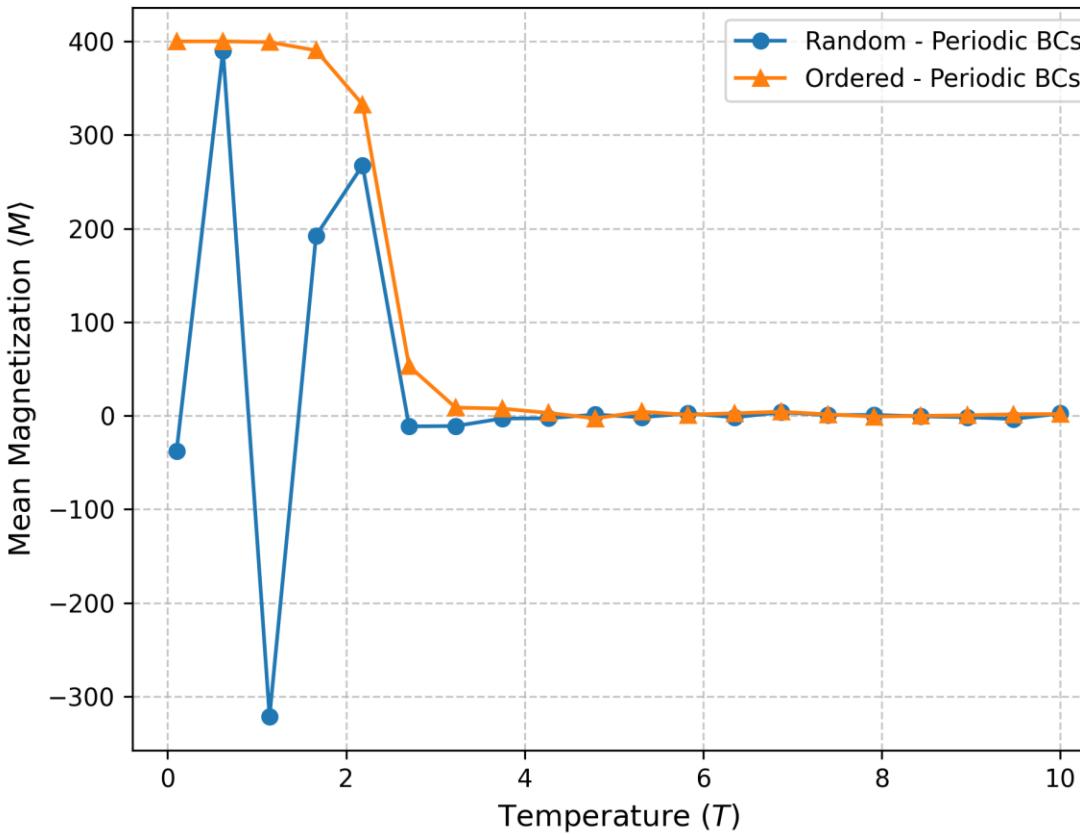
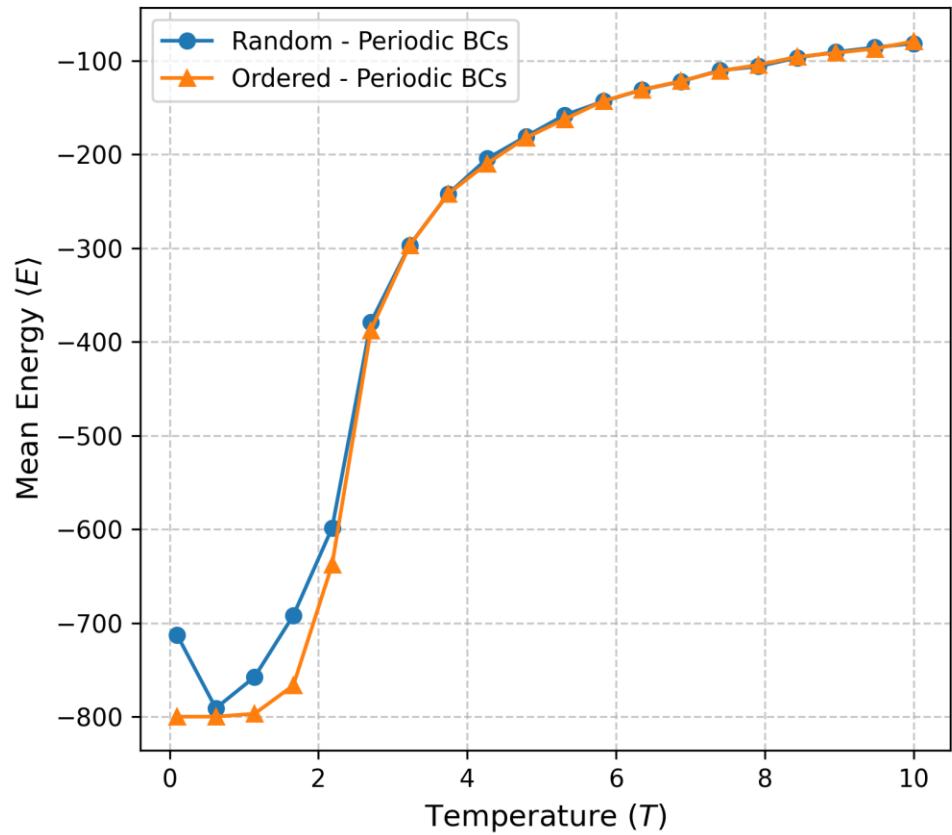
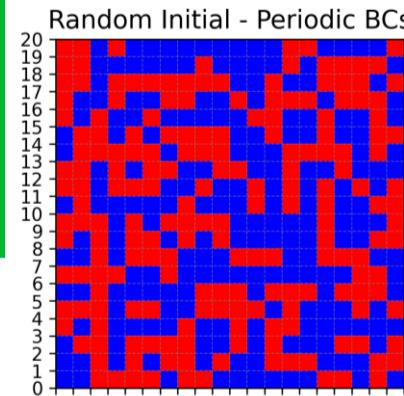
Una de las cosas más importantes de este modelo es que presenta una transición de fase.

$$T_c = \frac{2J}{k_B \log(\sqrt{2} + 1)}$$

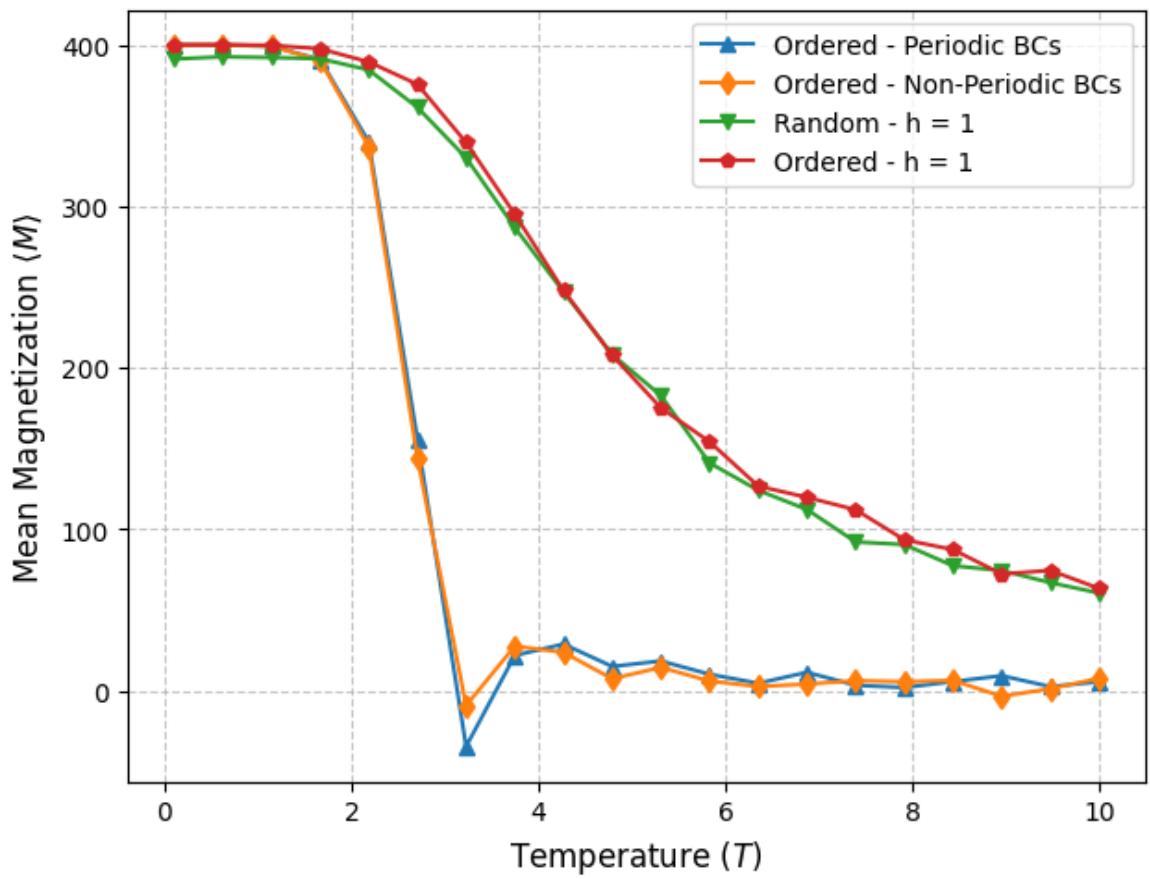
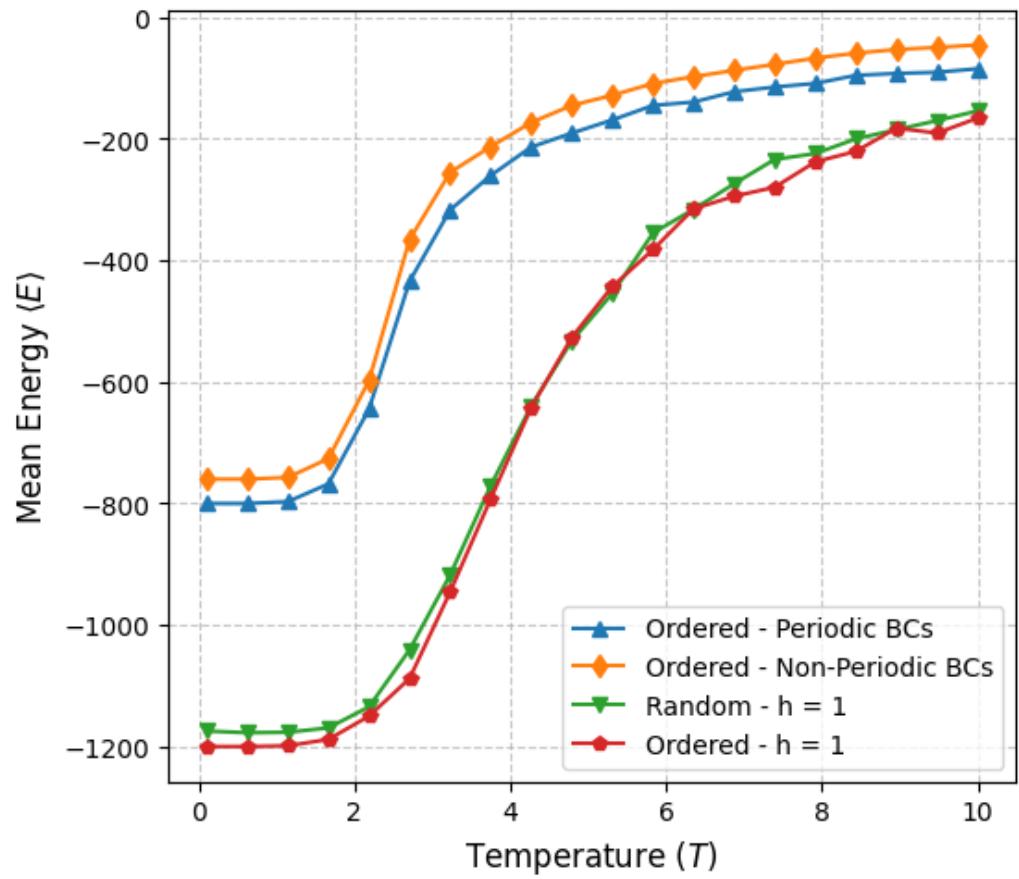




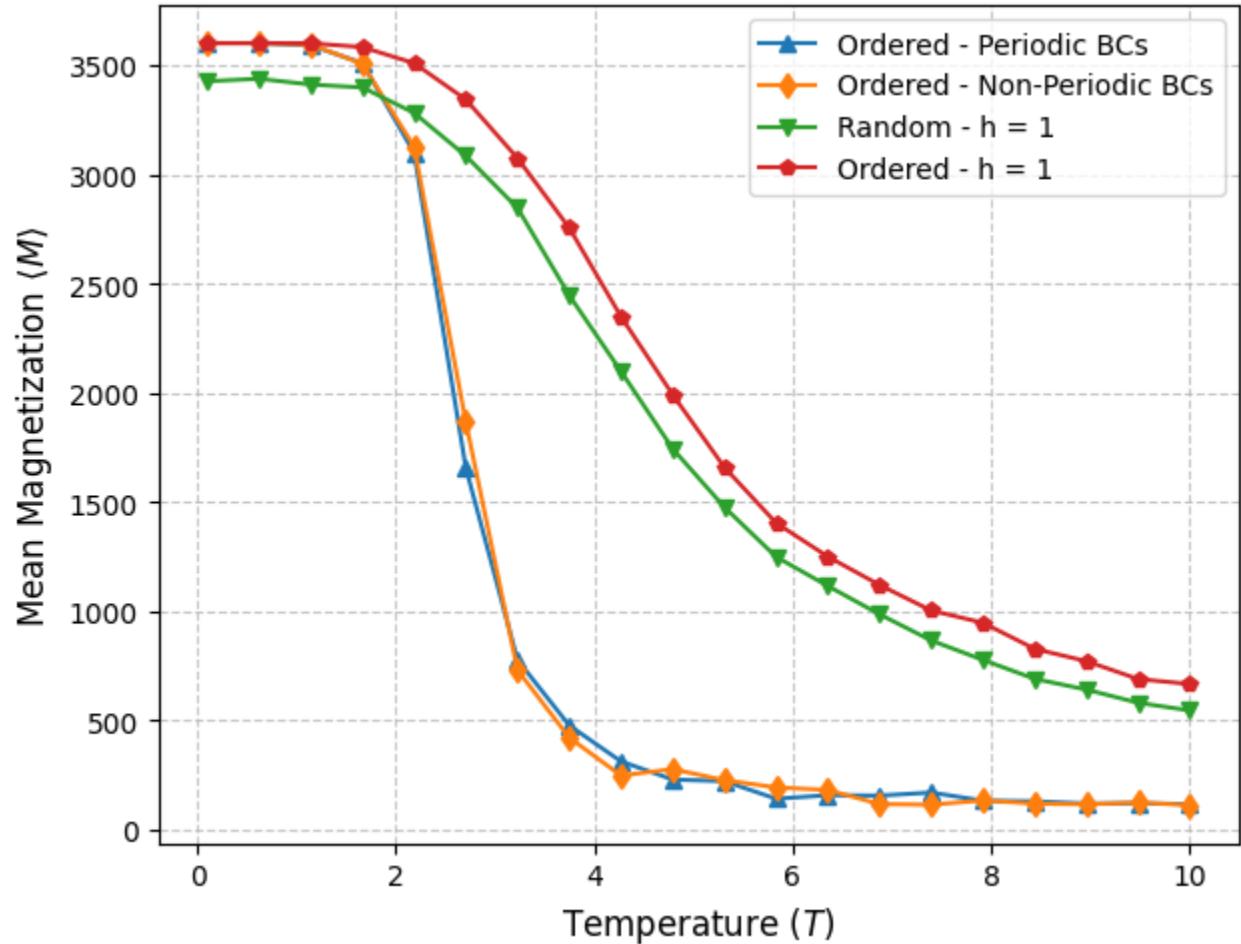
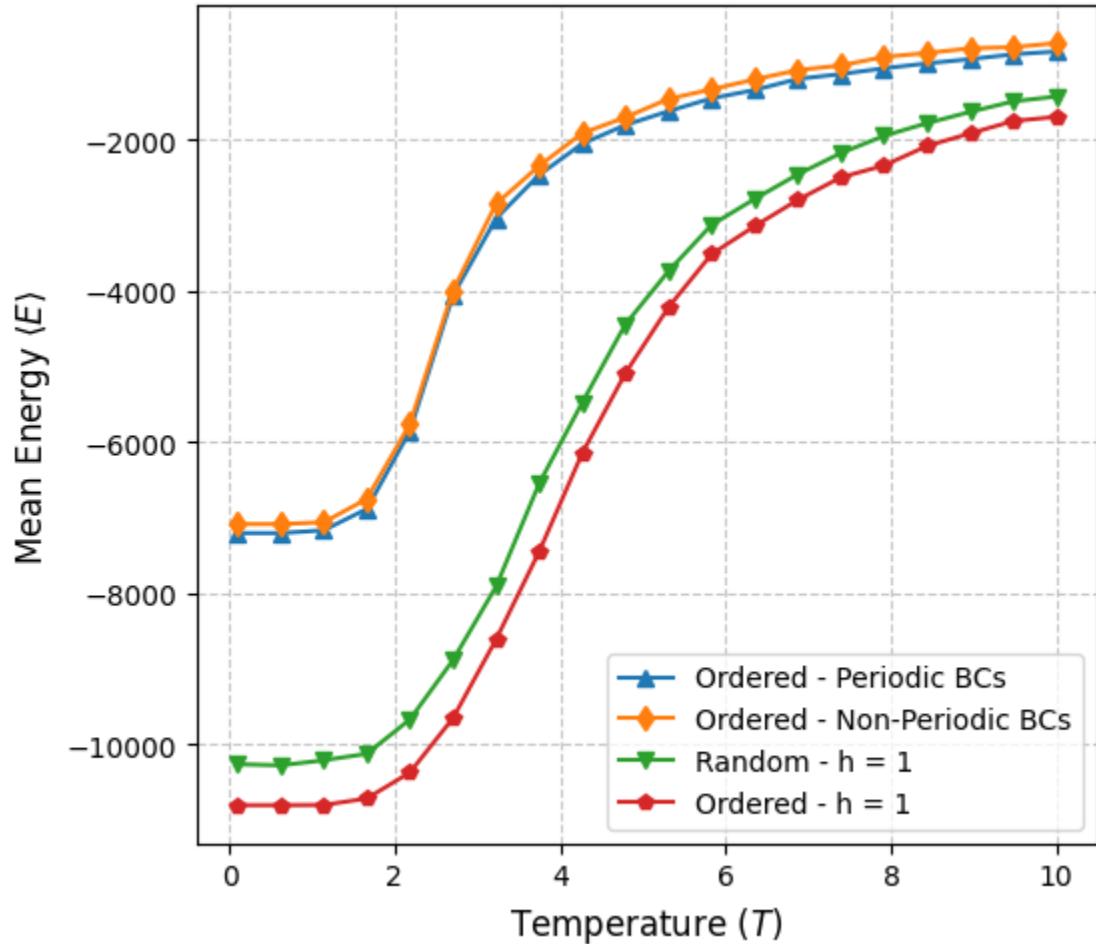
Barrido de temperatura ($L = 20$)



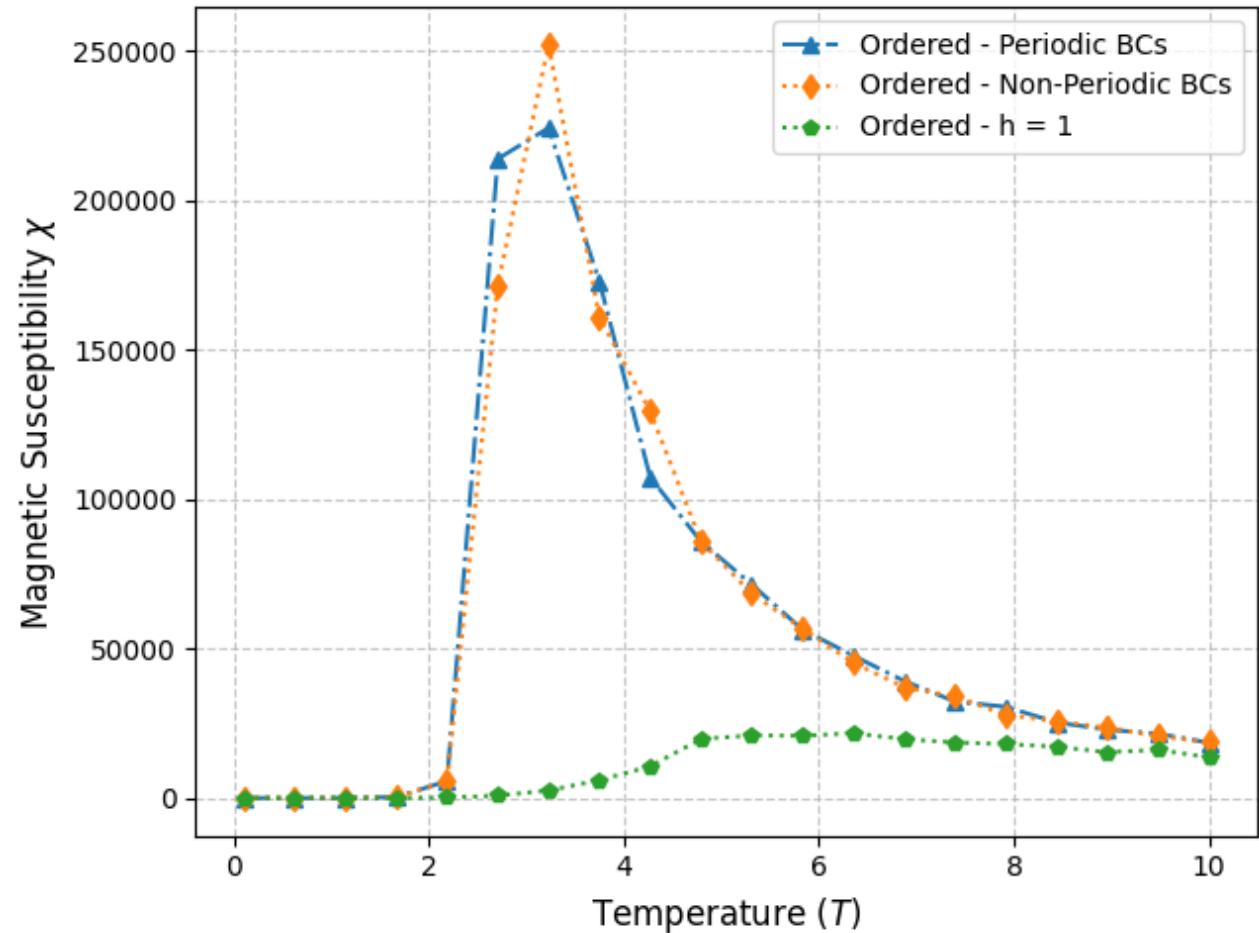
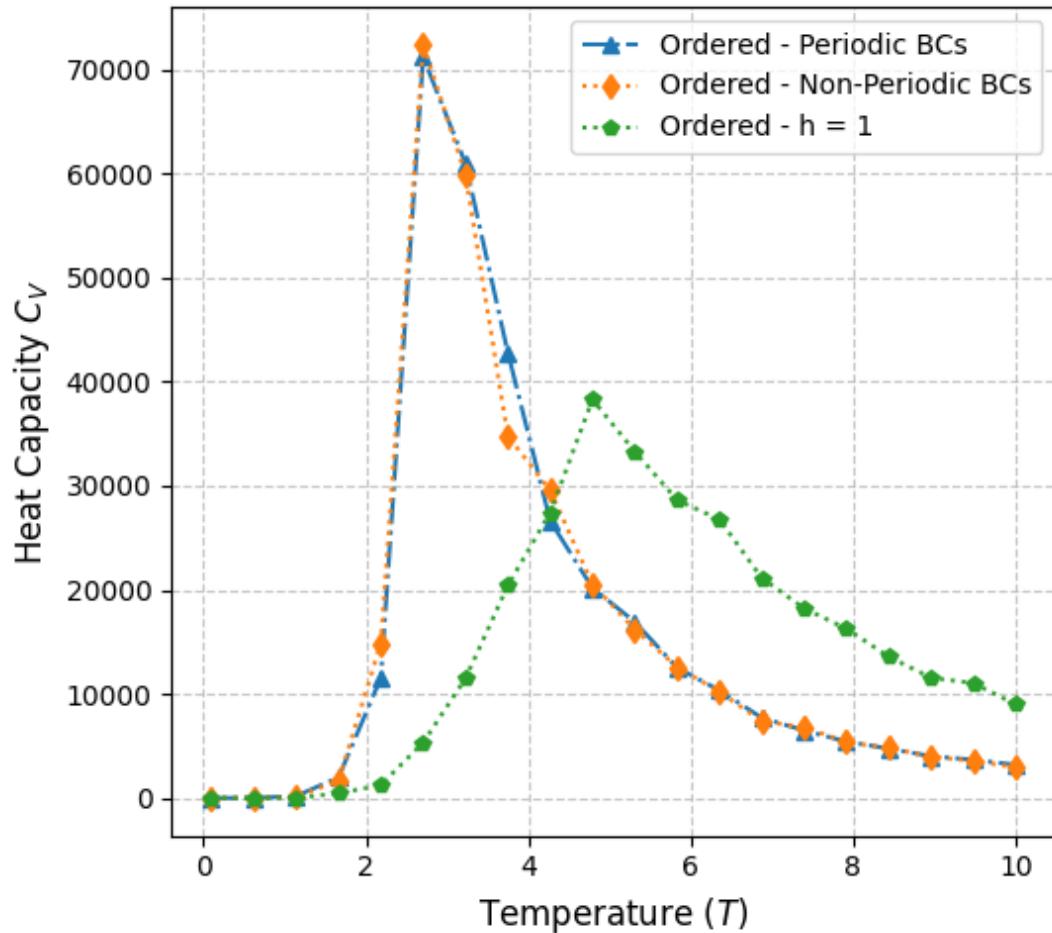
- Barrido de temperatura y ($h \neq 0$) ($L = 20$)



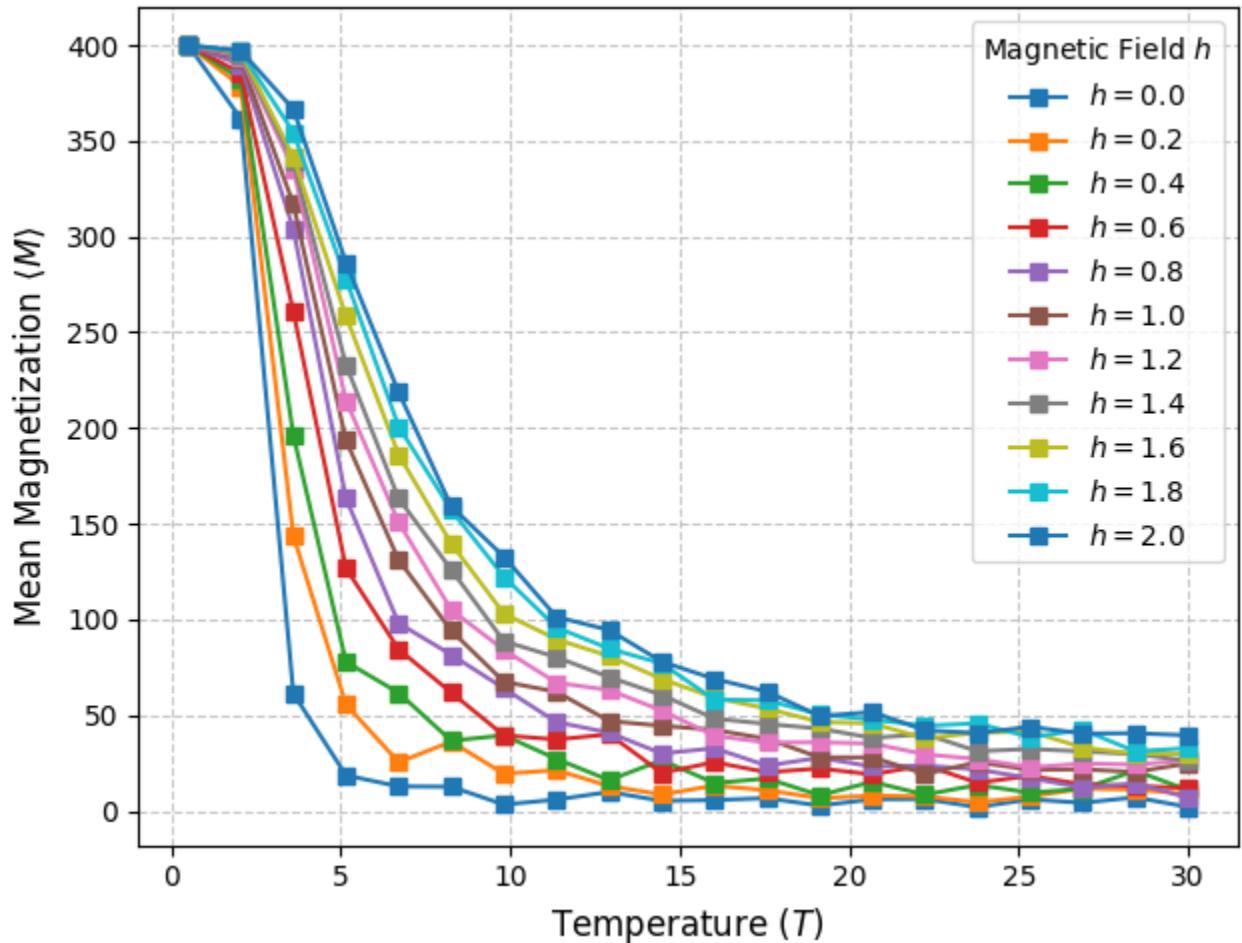
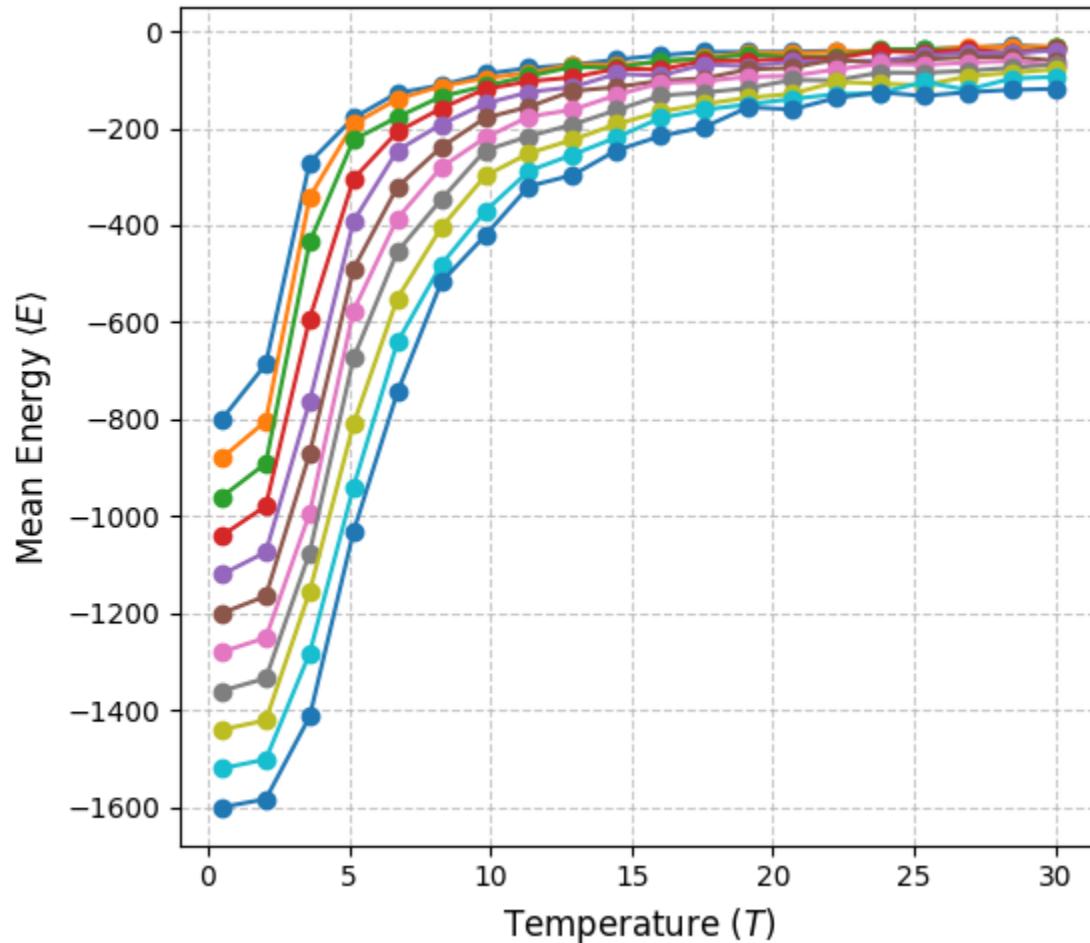
- Barrido de temperatura y ($h \neq 0$) ($L = 60$)



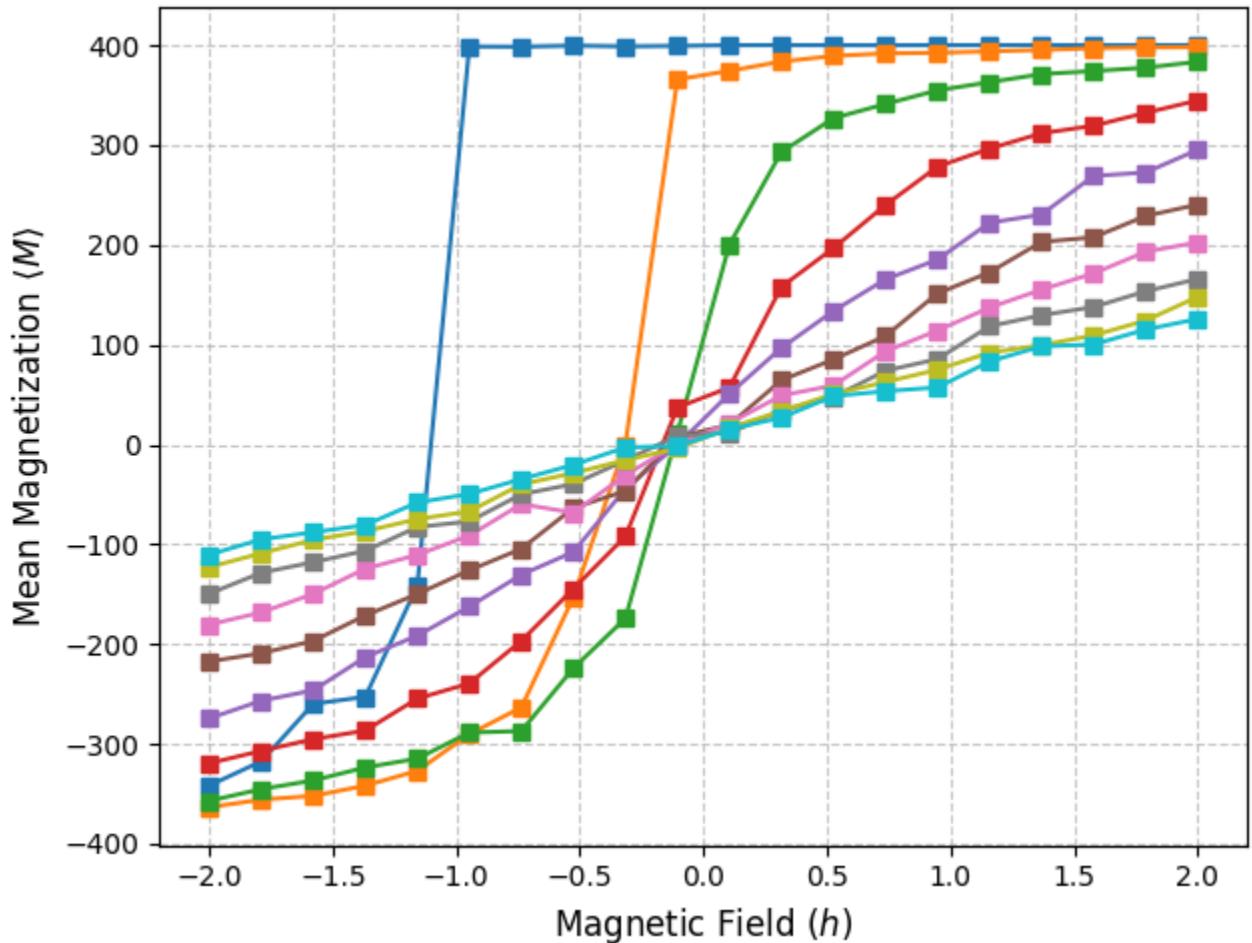
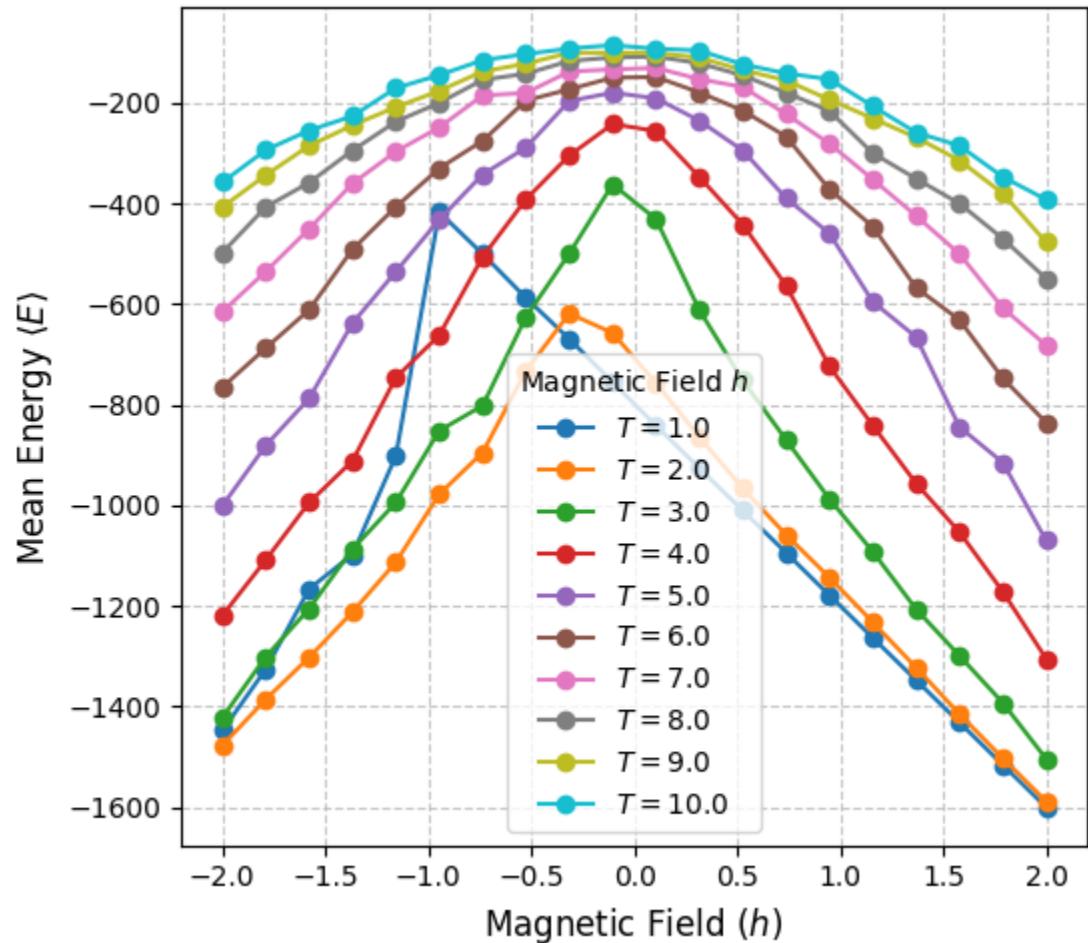
• Barrido de temperatura y ($h \neq 0$) ($L = 20$)



• Barrido de temperatura – Varios (h) ($L = 20$)

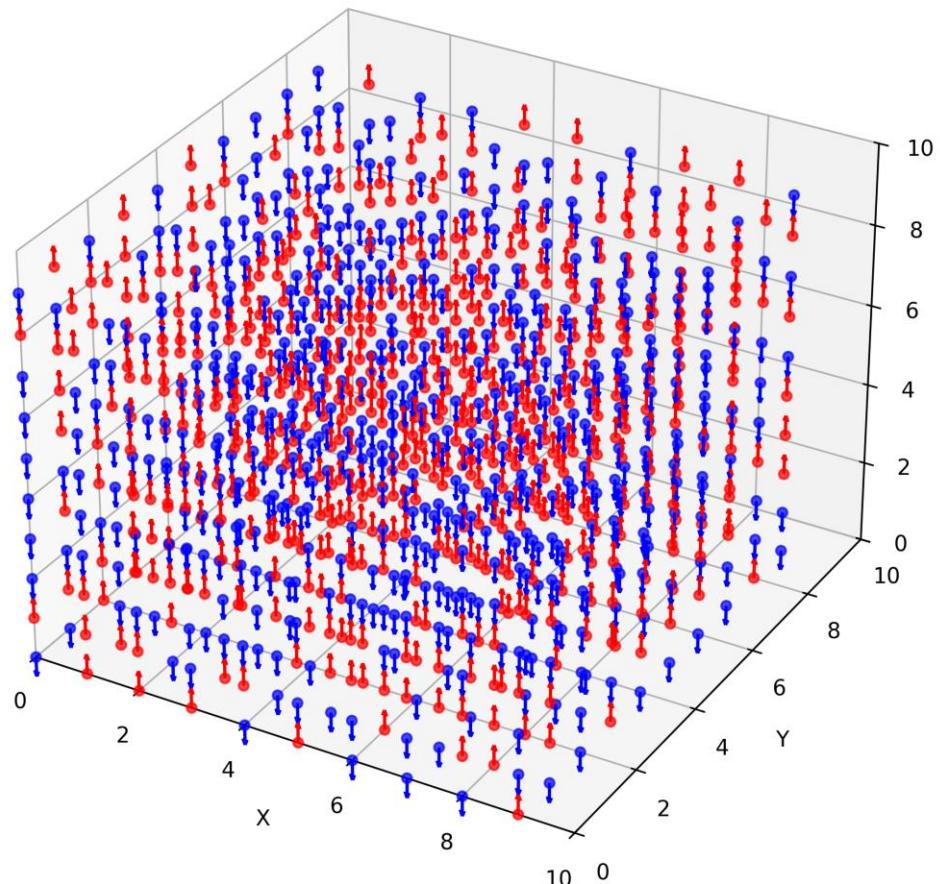


• Barrido de campo (h) ($L = 20$) Isotermas

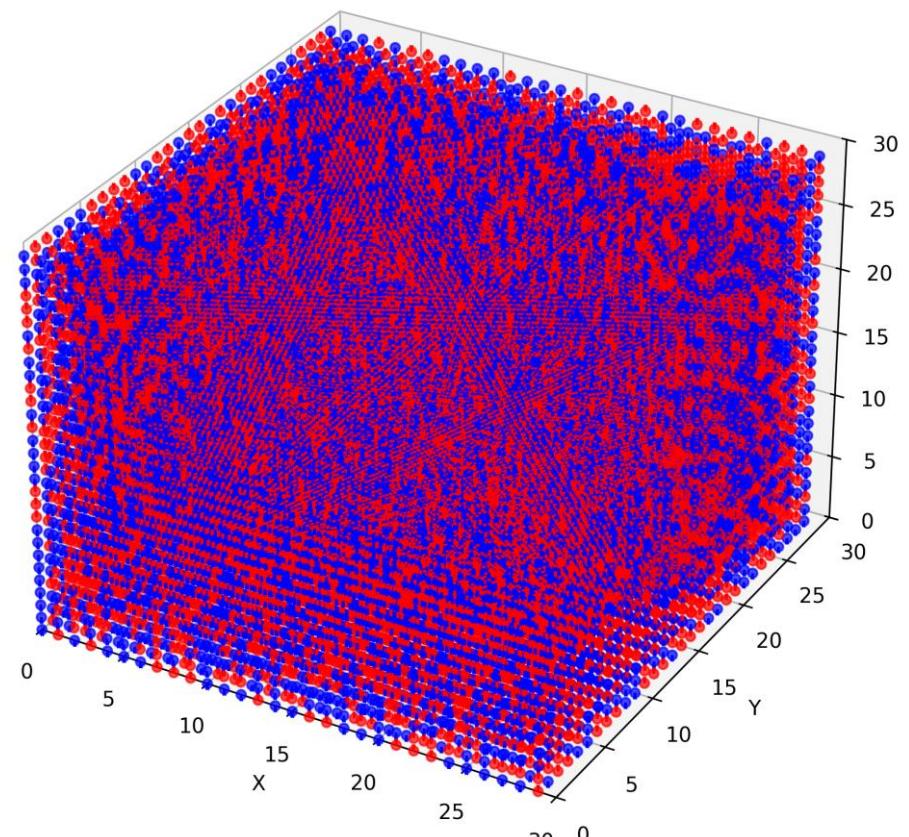


• Pasamos a 3D ($L = 10$) ($L = 30$) random

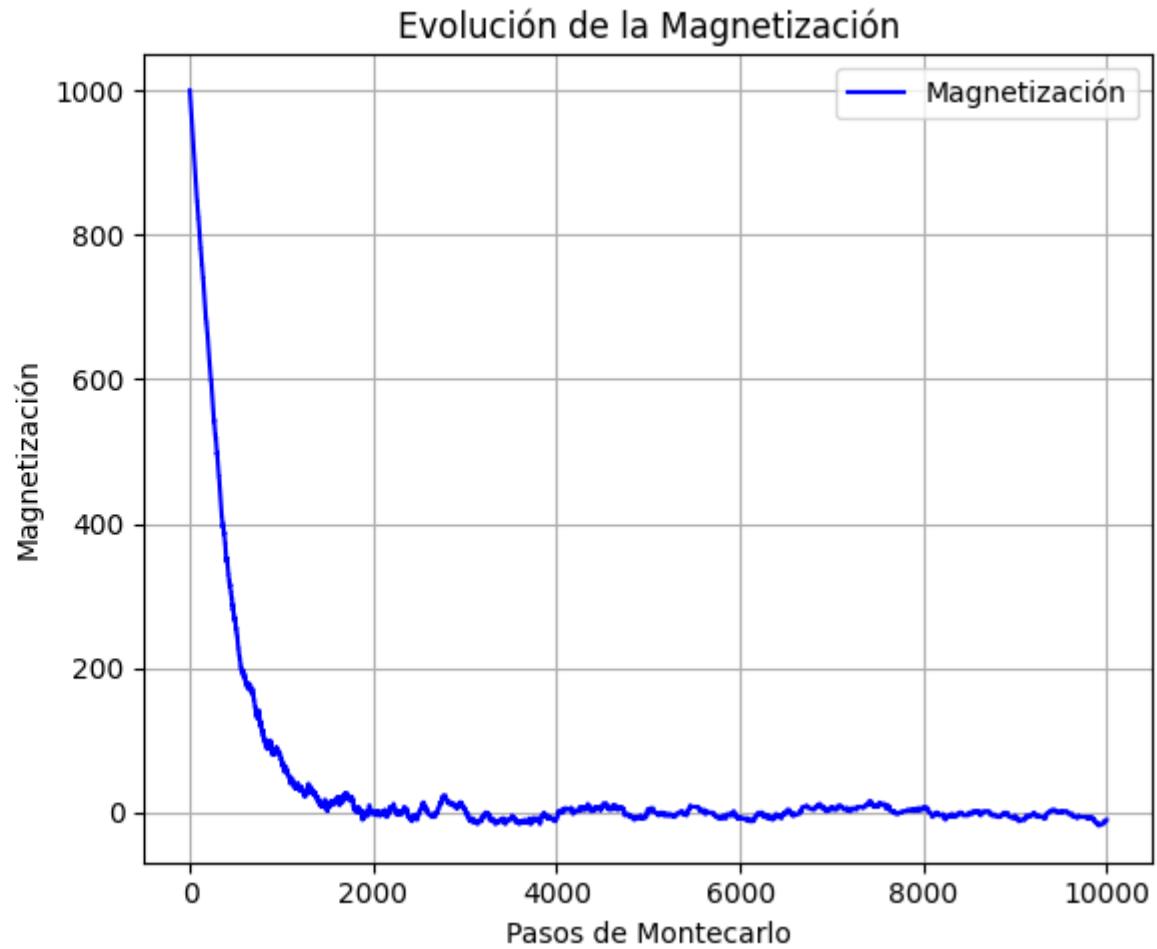
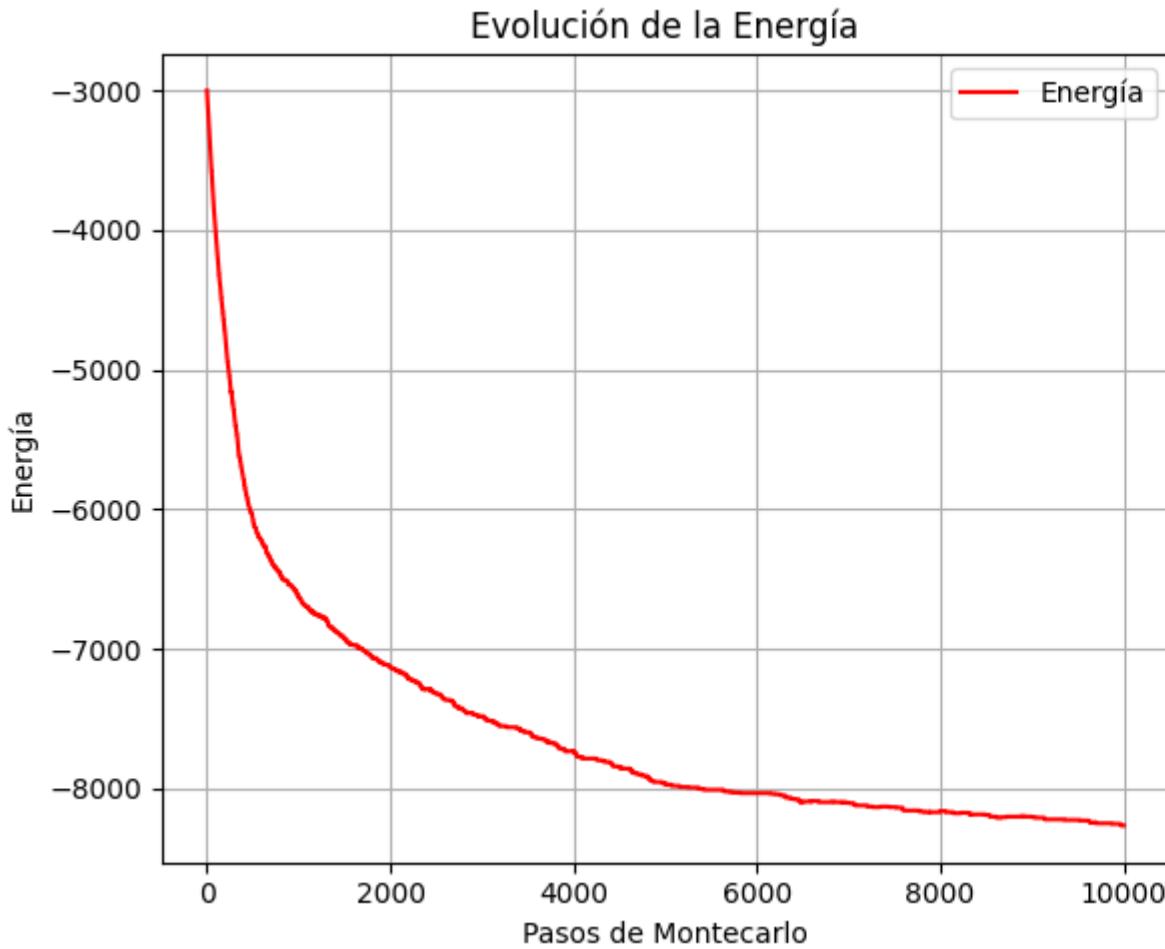
Configuración de espines en 3D



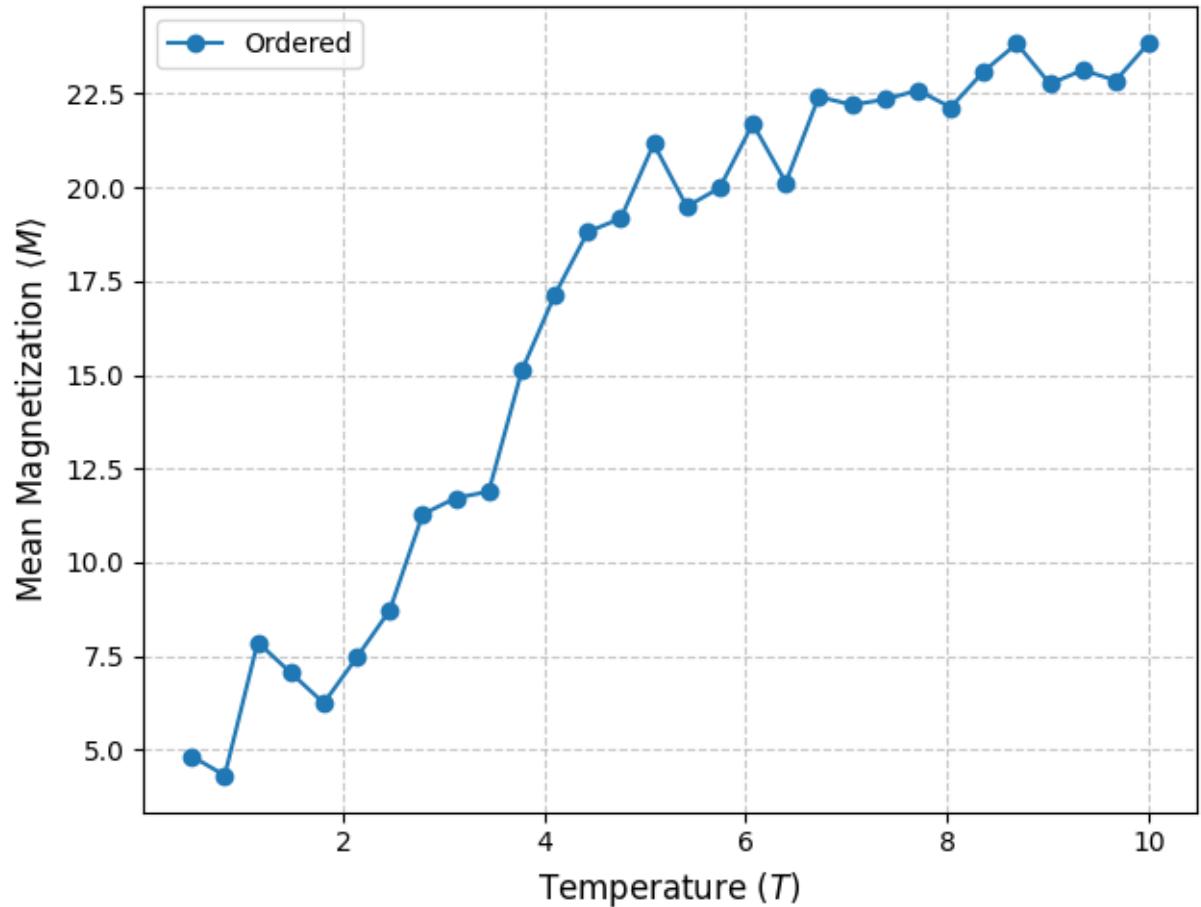
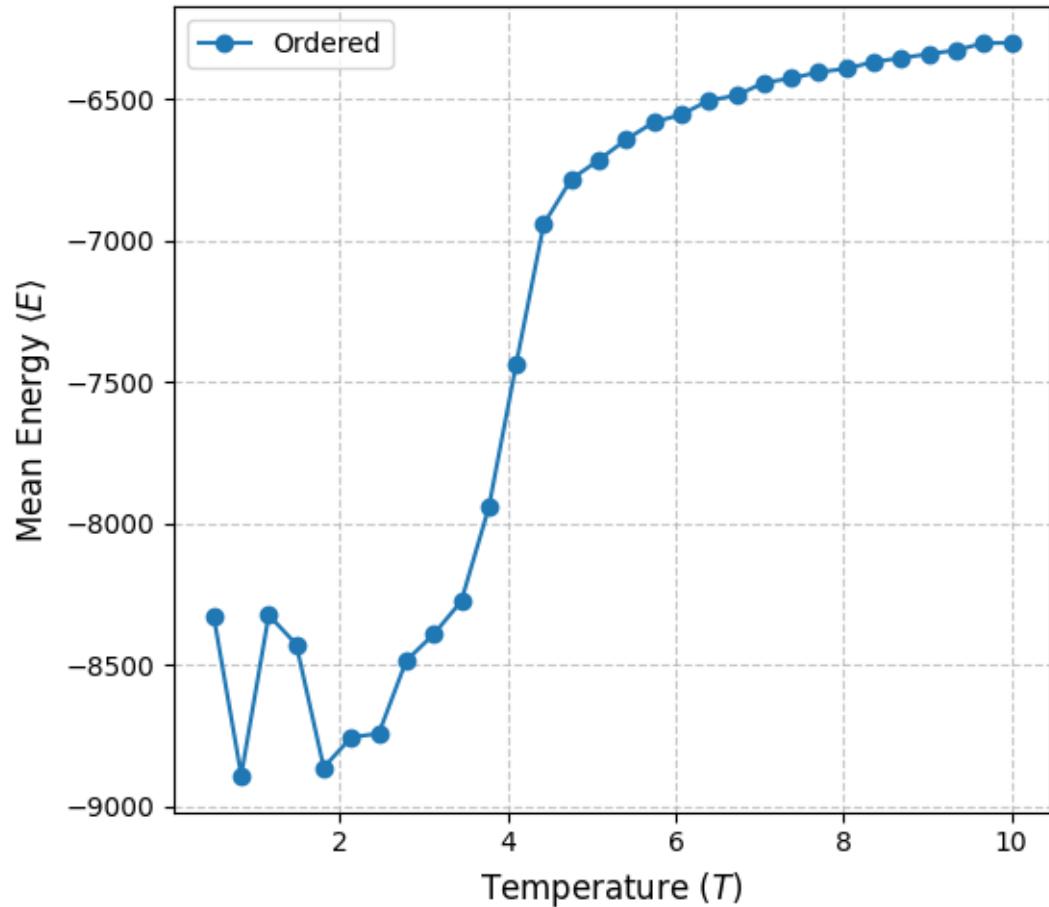
Configuración de espines en 3D



• Como evoluciona el sistema - random



• Como evoluciona el sistema - random



● Conclusiones y perspectivas

Análisis de transiciones de fase: Se estudió la evolución de la magnetización y la energía del sistema, observando cambios de fase que caracterizan la transición del orden al desorden en función de la temperatura.

Exploración en 3D: Mientras que el comportamiento en 2D está bien comprendido, el caso tridimensional requiere un análisis más profundo para describir con mayor precisión sus propiedades críticas y su transición de fase.





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• Anexo A: Espines bloqueados

Spin Configurations with Blocking ($h = 20.00$, $L = 20$)

