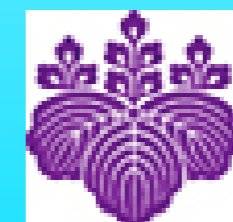
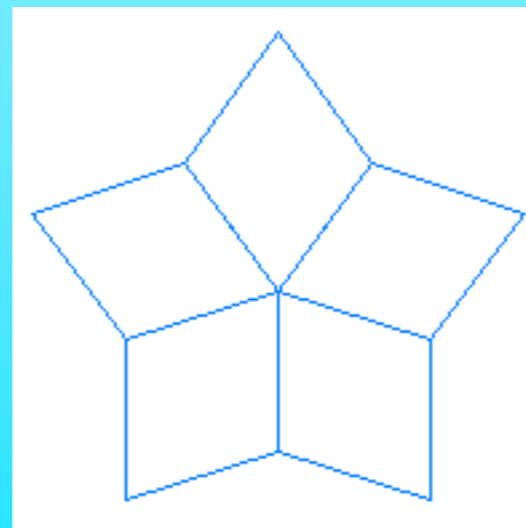
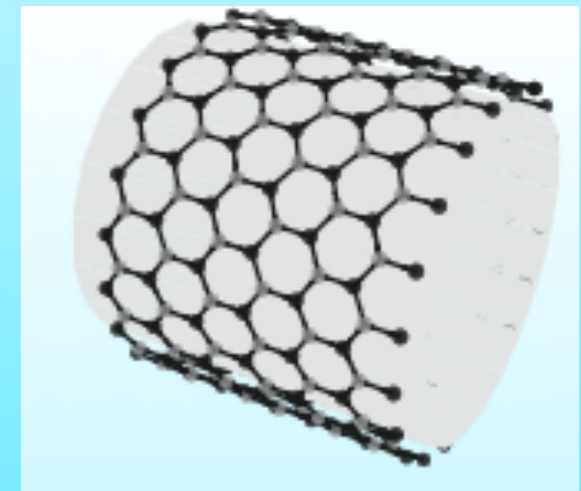


# 物質中にあるフラクタル及び 自己相似な構造

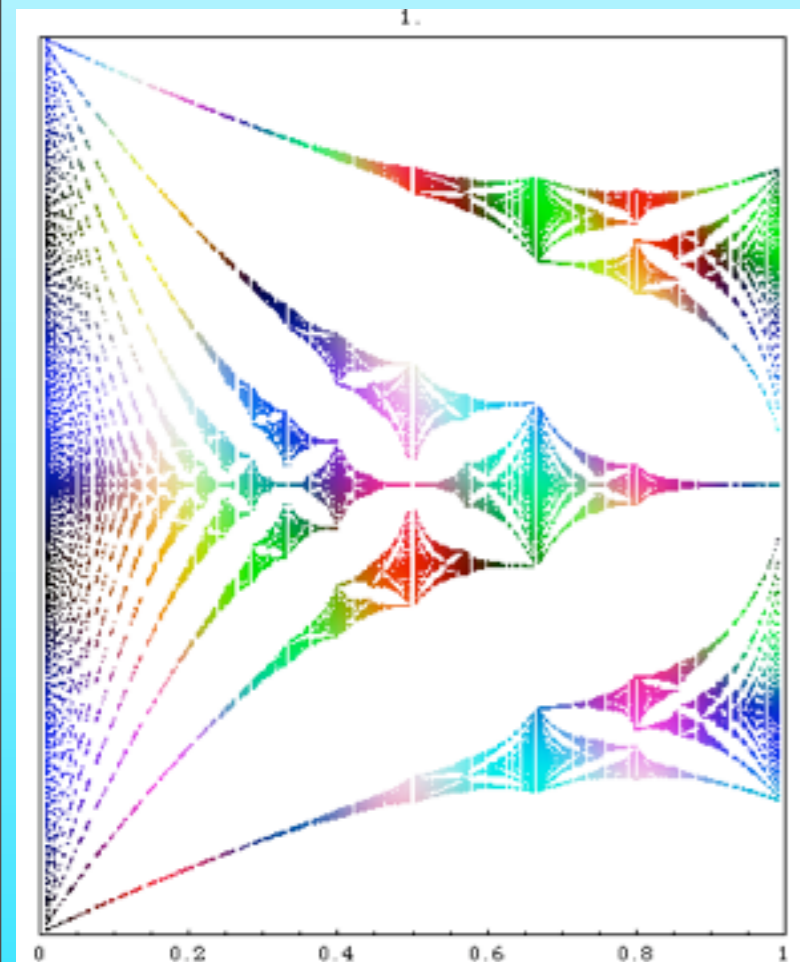
美しい理論構造とその背後に潜む理論物理

## 大学説明会 2009

筑波大学 理工学群 物理学類  
凝縮系理論

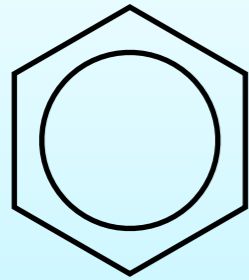


筑波大学  
University of Tsukuba

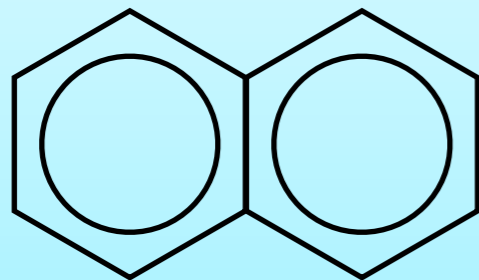


# Graphene??

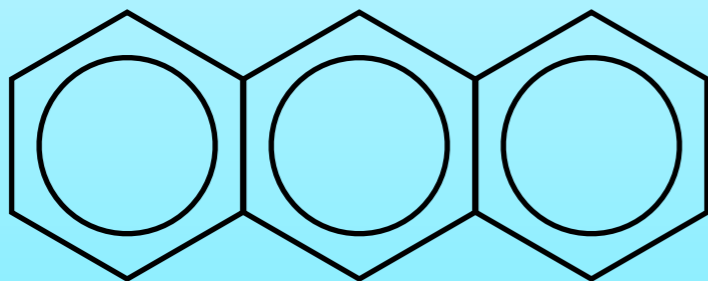
## ★ $\pi$ -electron systems



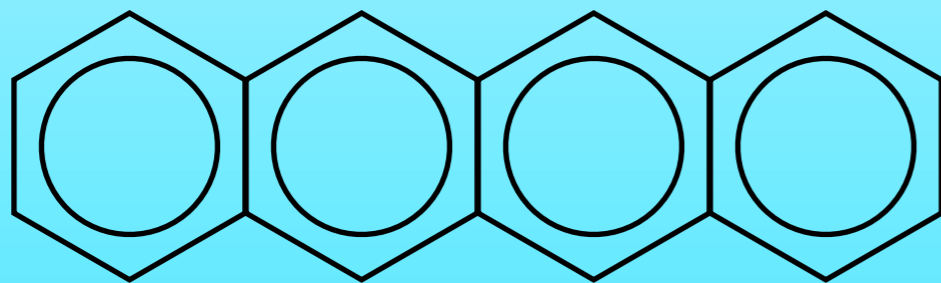
benzene



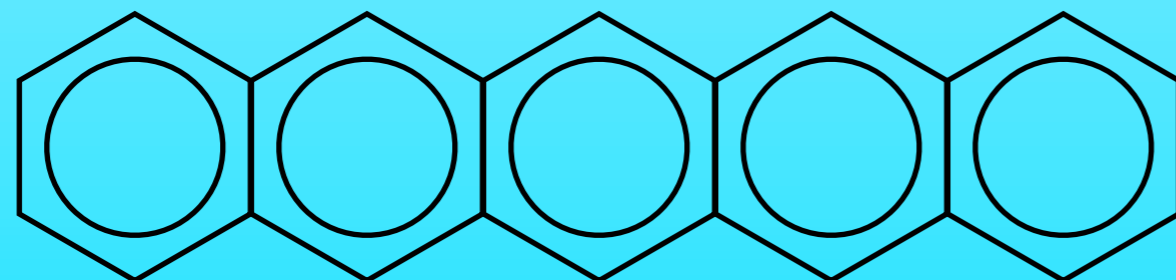
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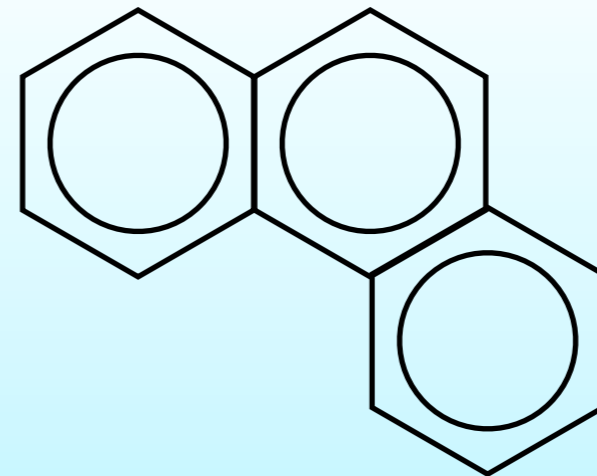
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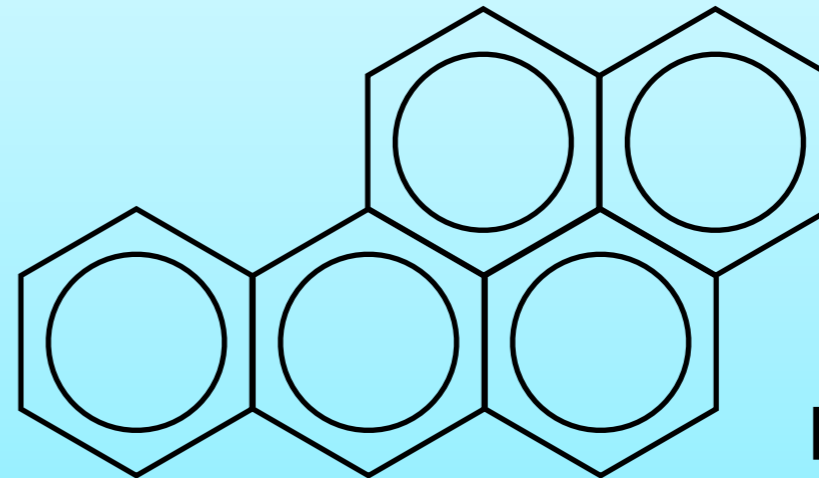
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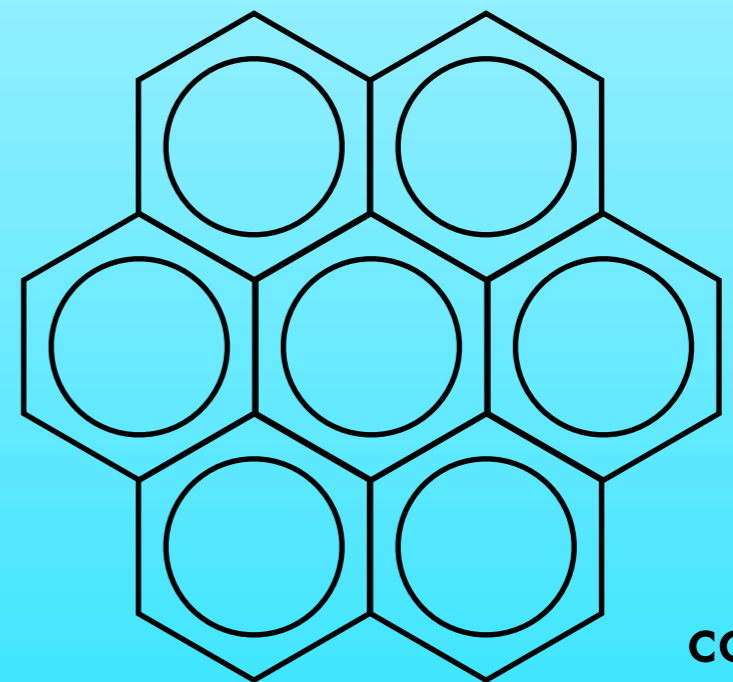
pentacene



phenanthrene



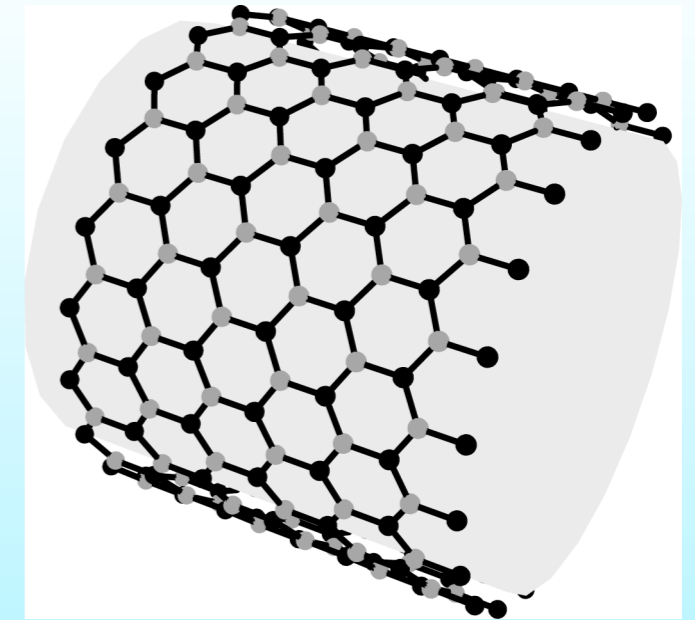
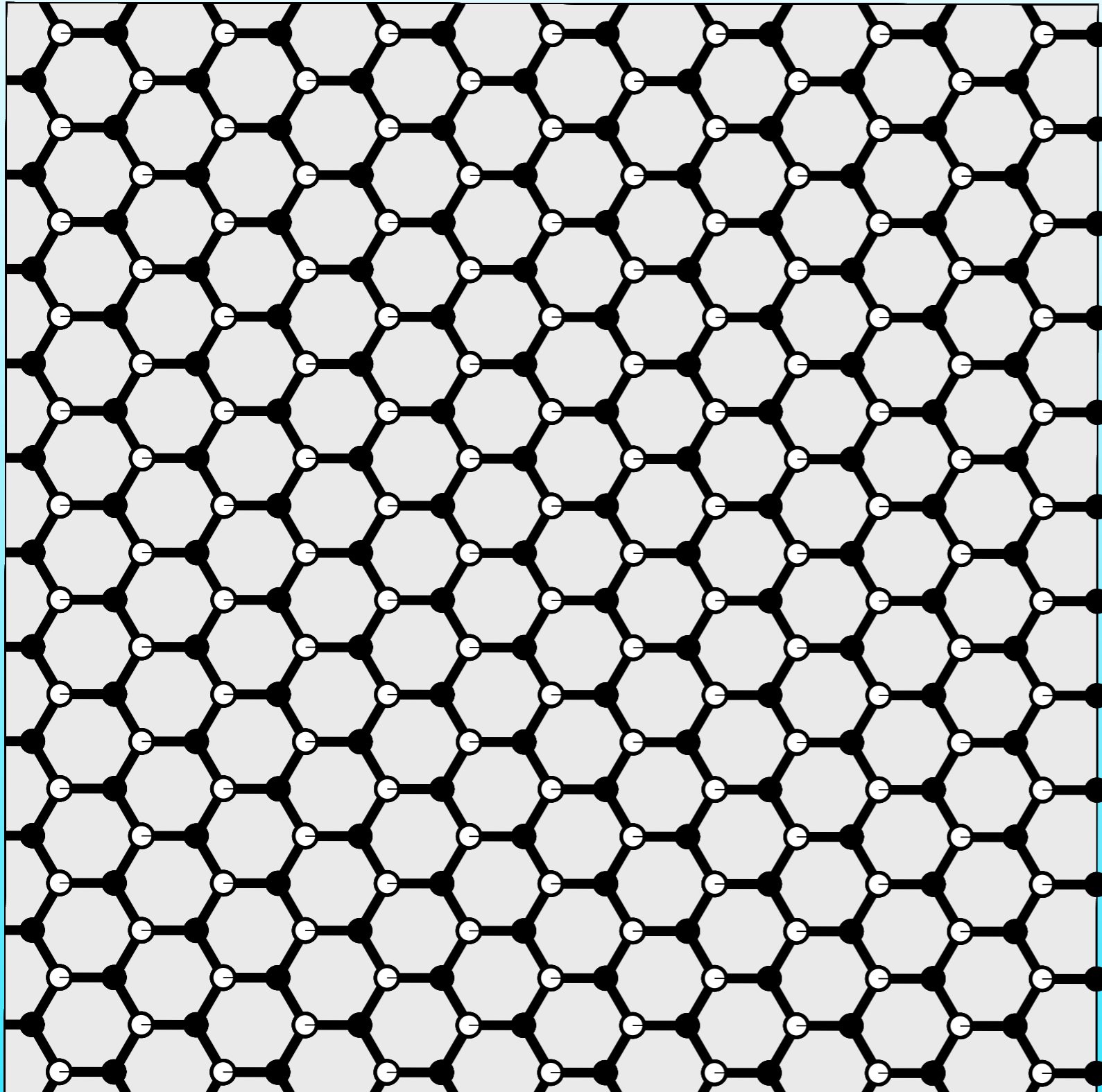
benzopyrene



coronene

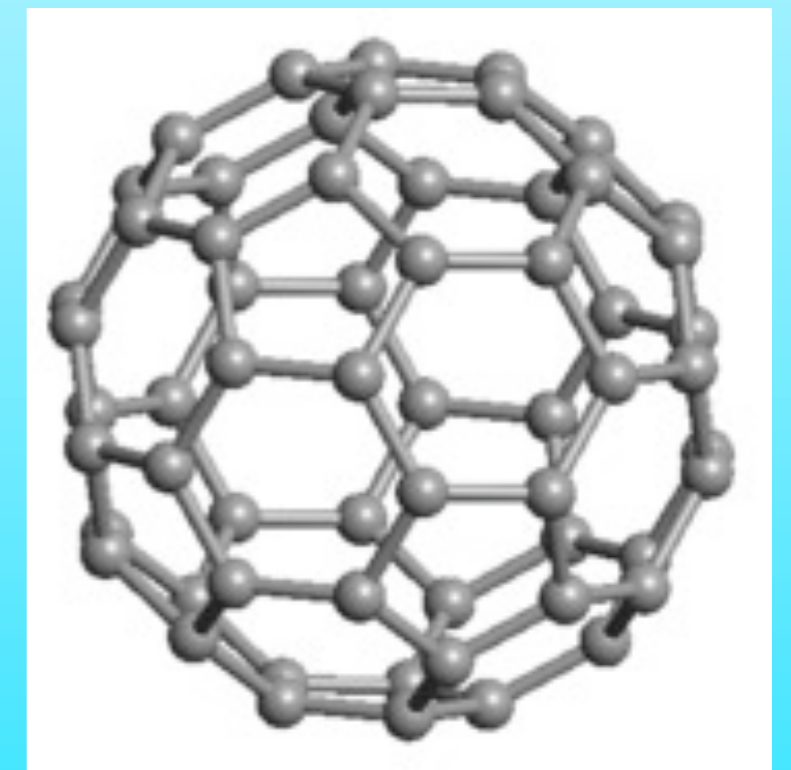
# Graphene??

Graphene



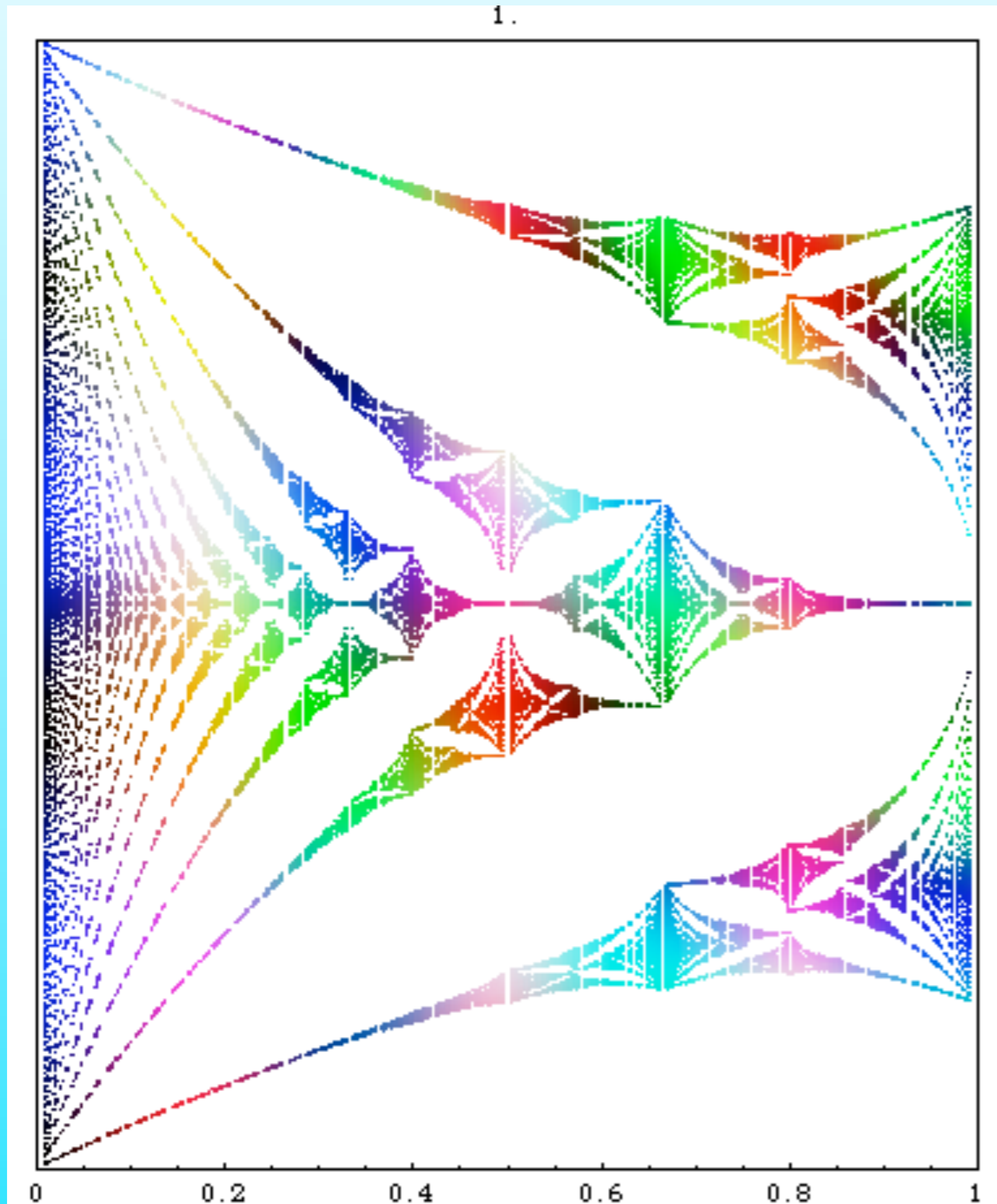
Carbon Nano-Tube

Fulerene

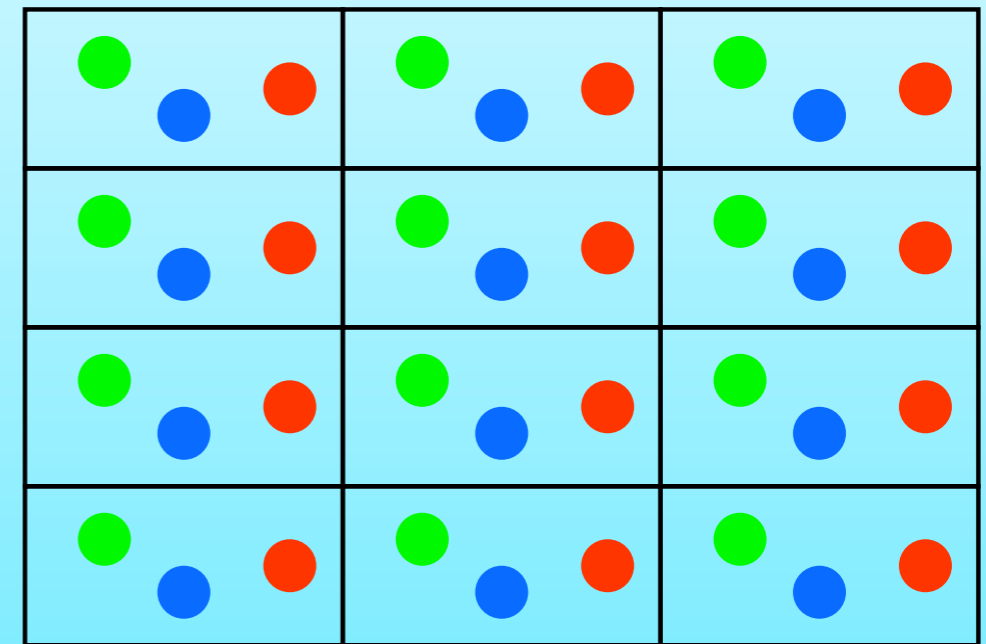


# Hofstadterの蝶

周期的ポテンシャル中での磁場中の電子のエネルギー準位

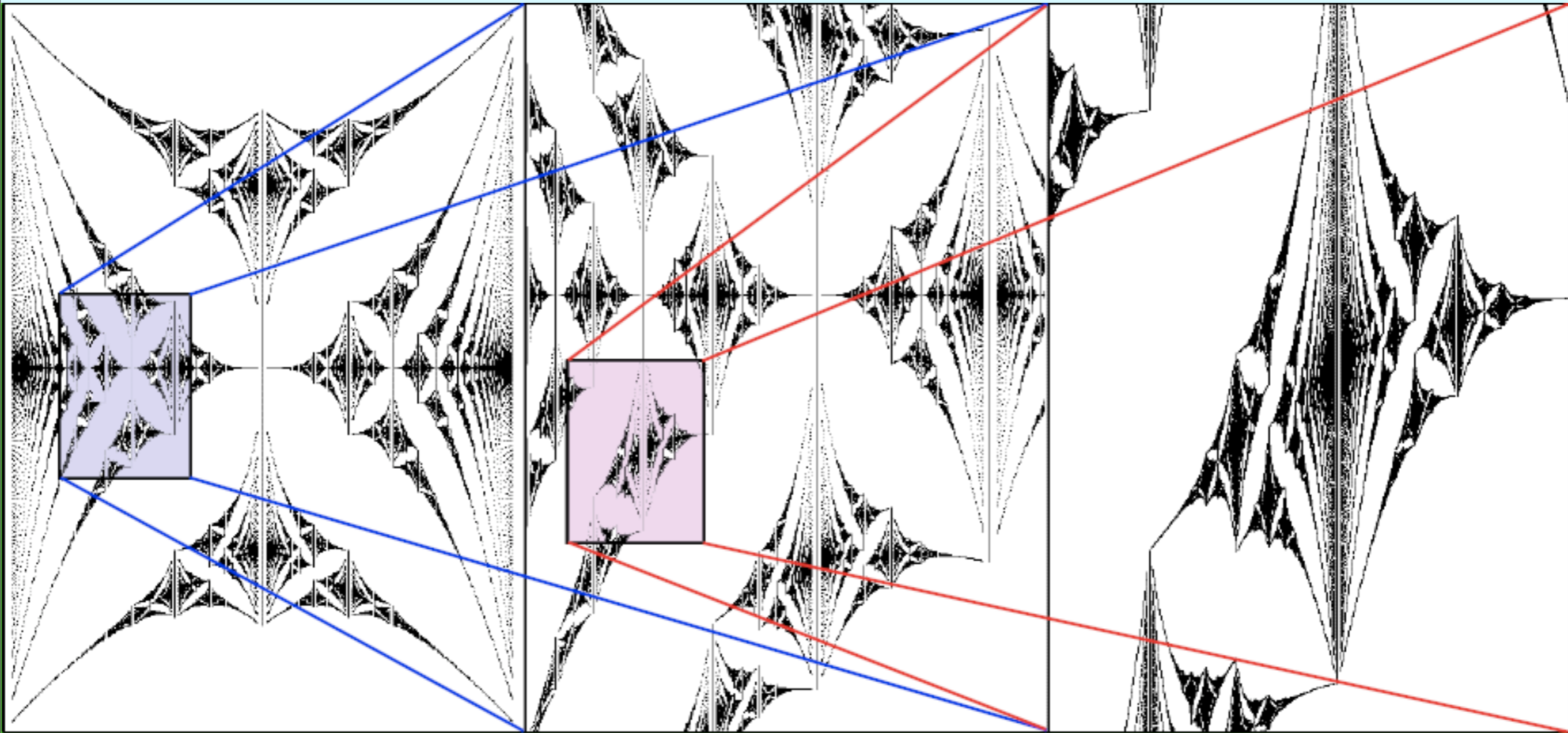


結晶格子は周期的ポテンシャルをつくる



典型的なフラクタル構造

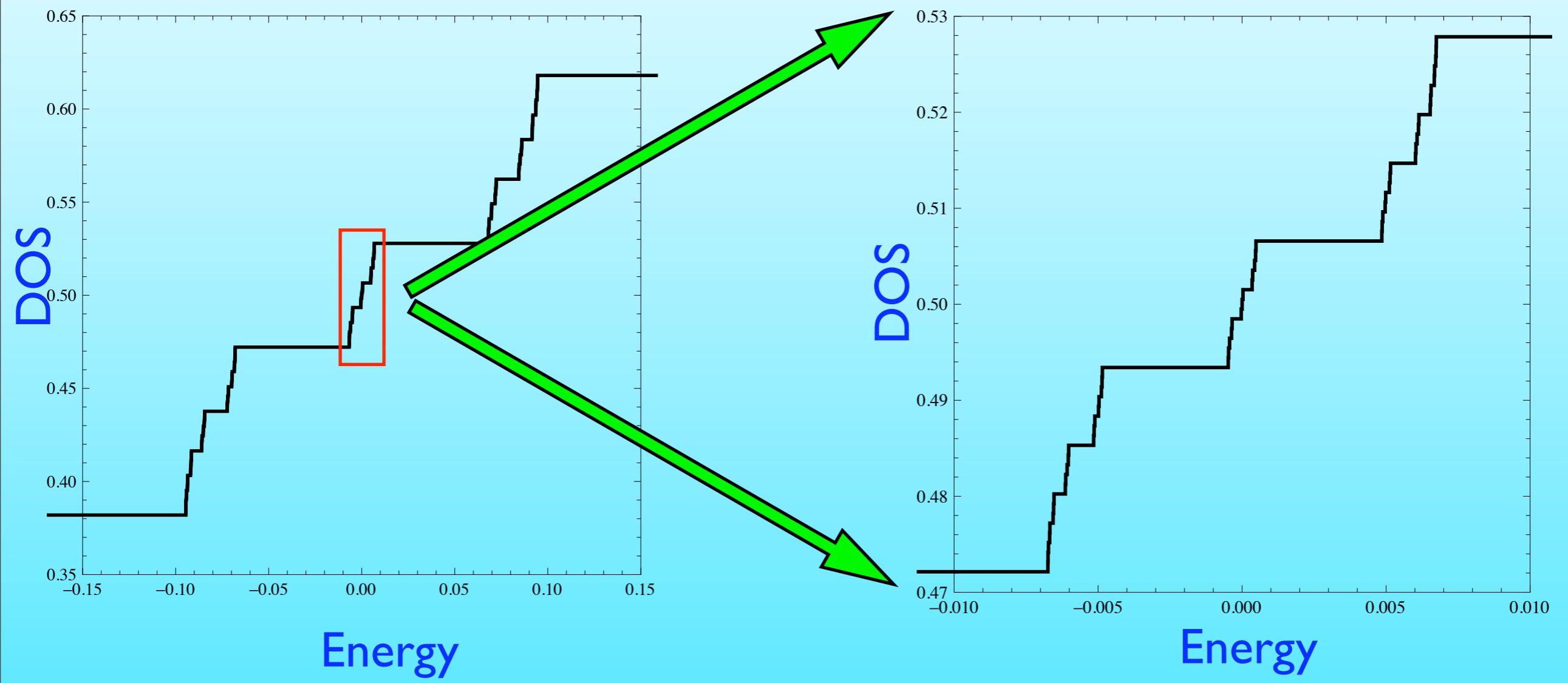
# *Hofstadter's Butterfly* *Self-similar*



*Fractal in condensed matter*

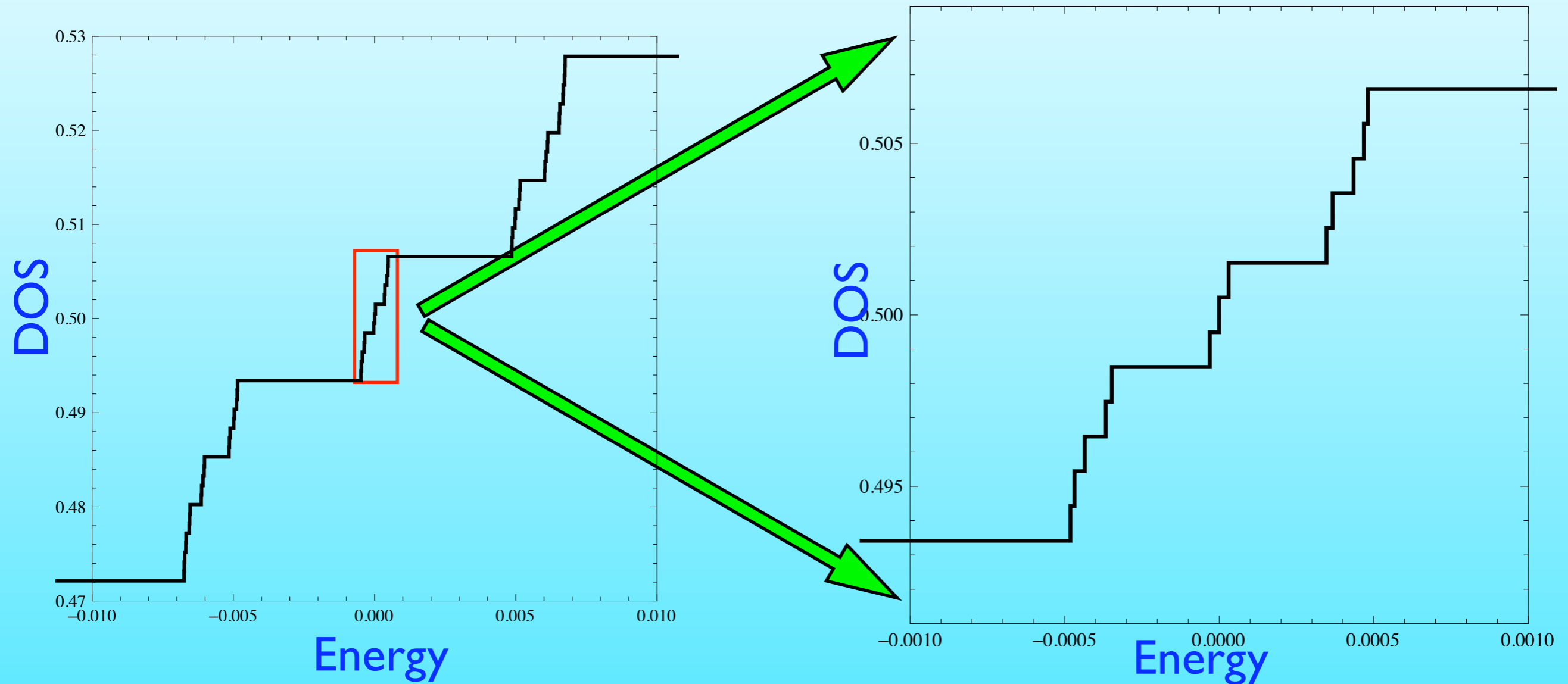
# 悪魔の階段

☆ Integrated Density of States of the Hofstadter's Butterfly

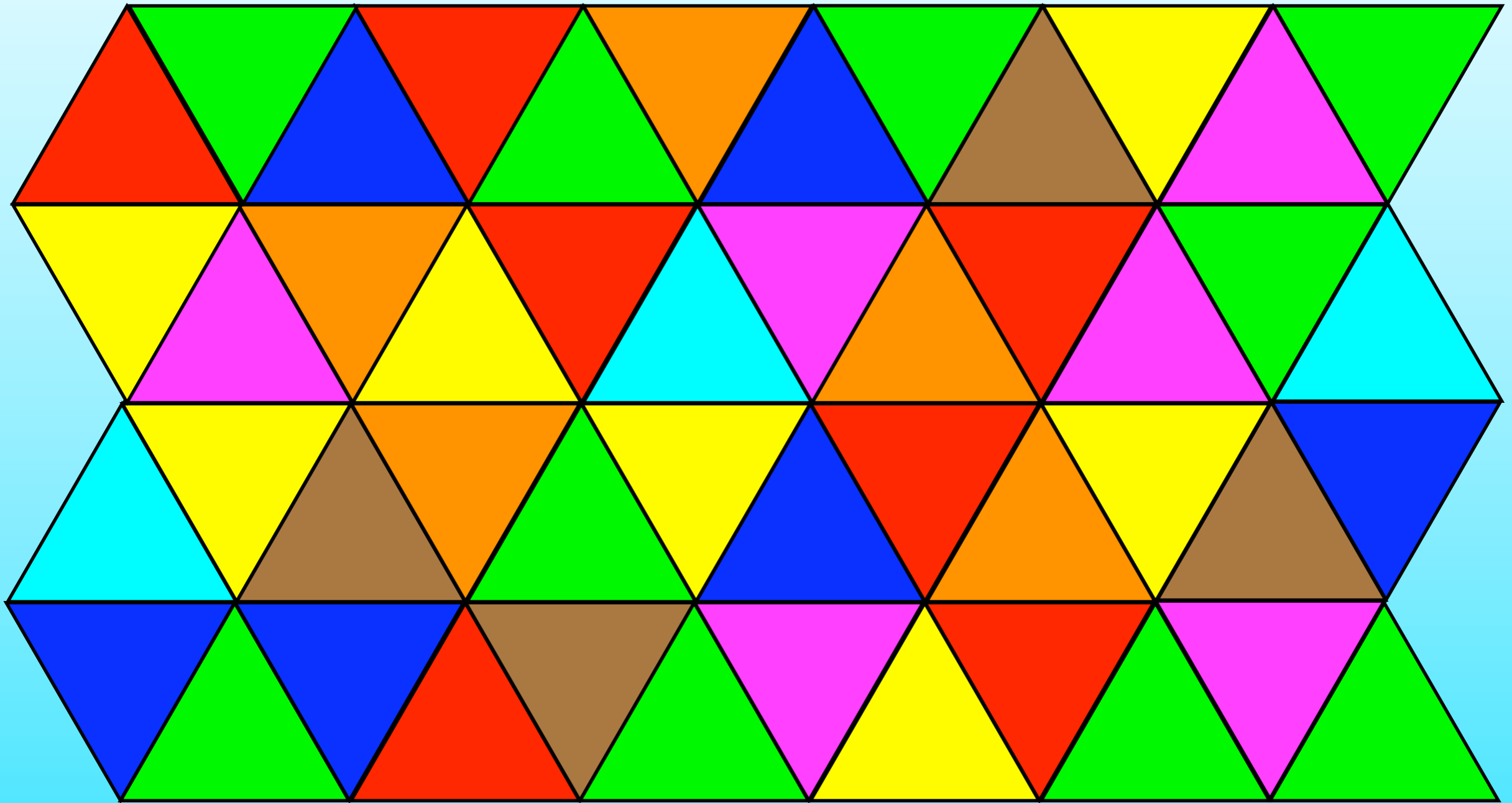


# 悪魔の階段

## ☆ Integrated Density of States of the Hofstadter's Butterfly



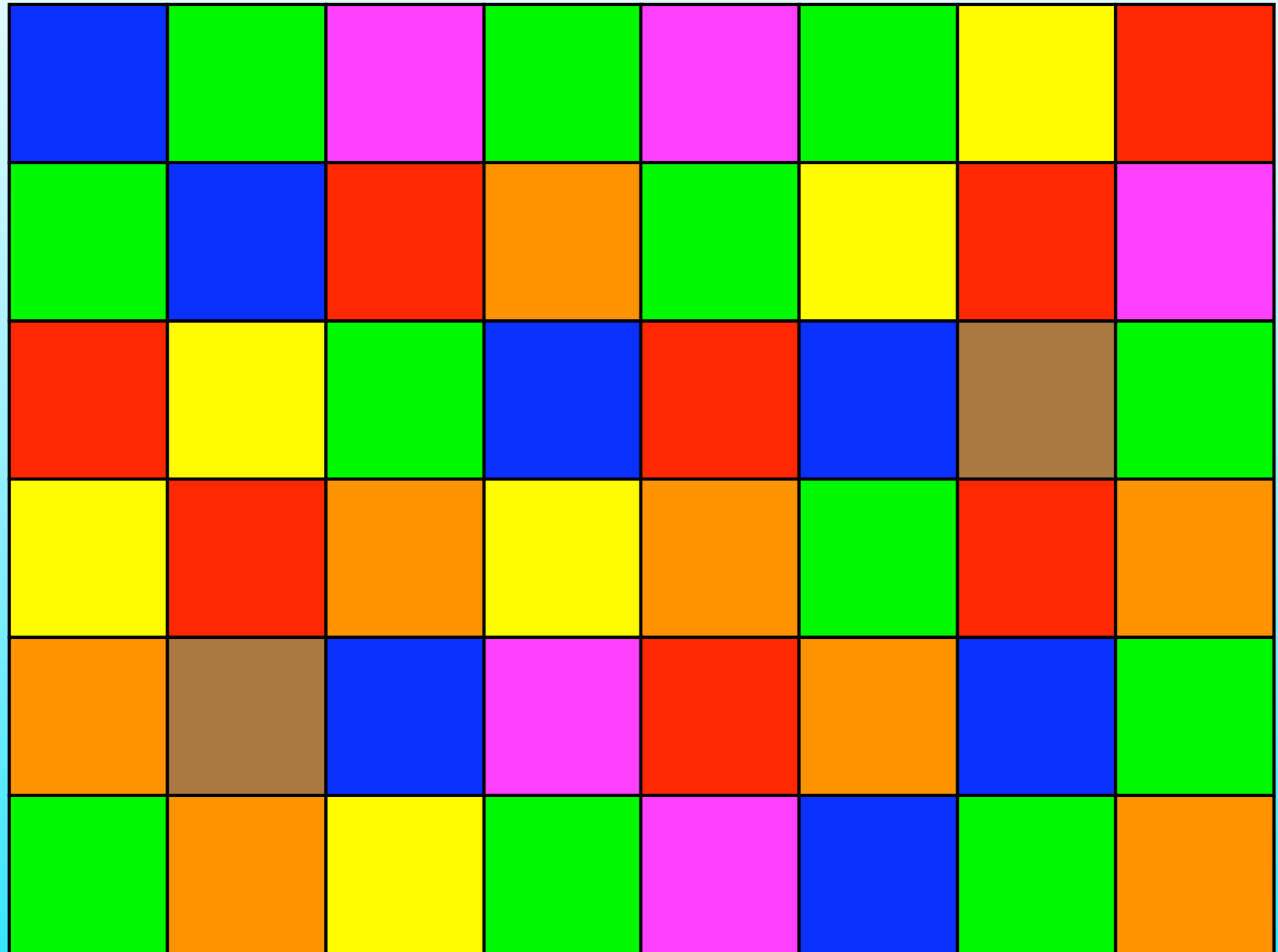
# 回転対称性と空間の埋め尽くし



OK

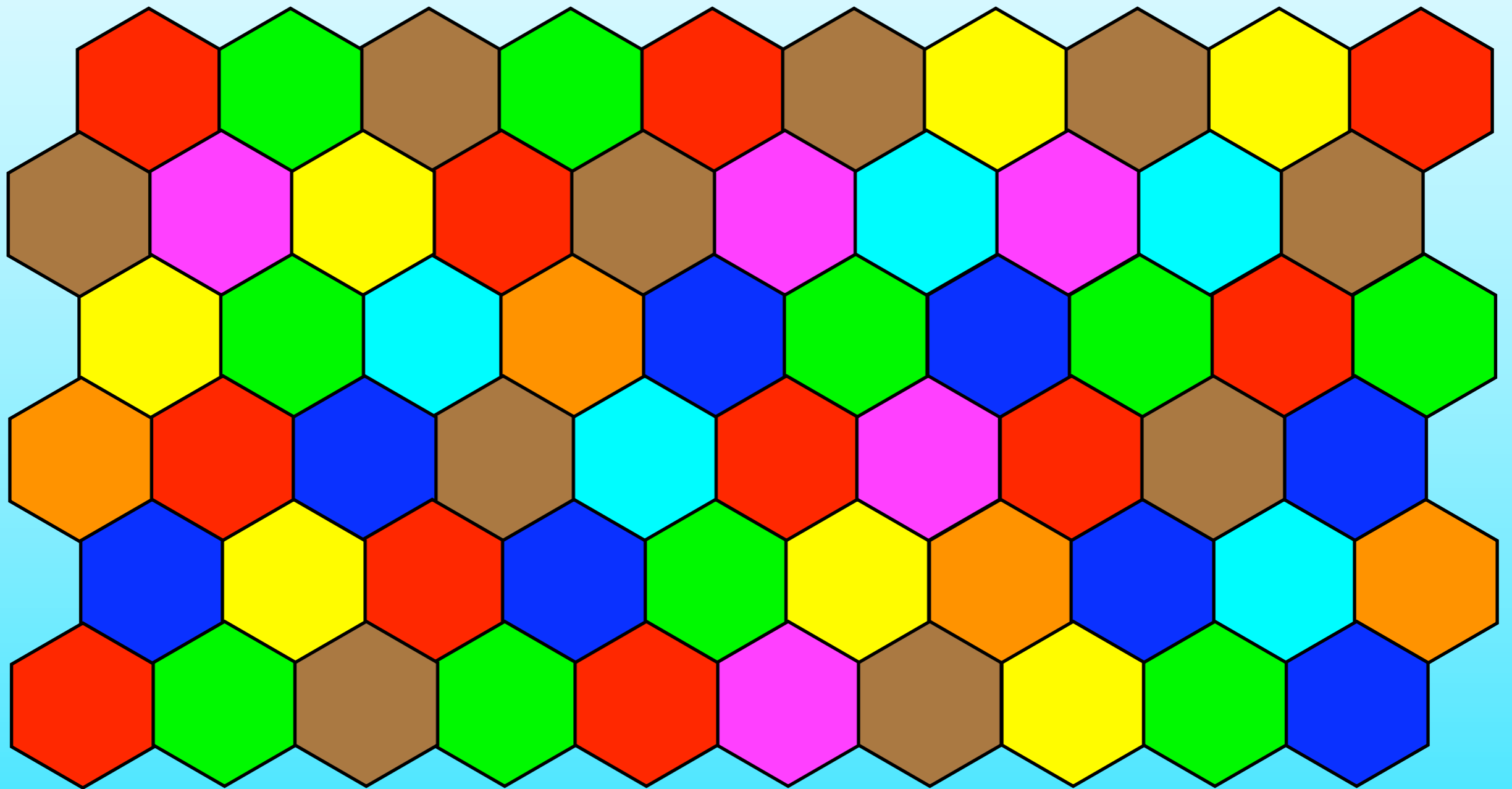


# 回転対称性と空間の埋め尽くし



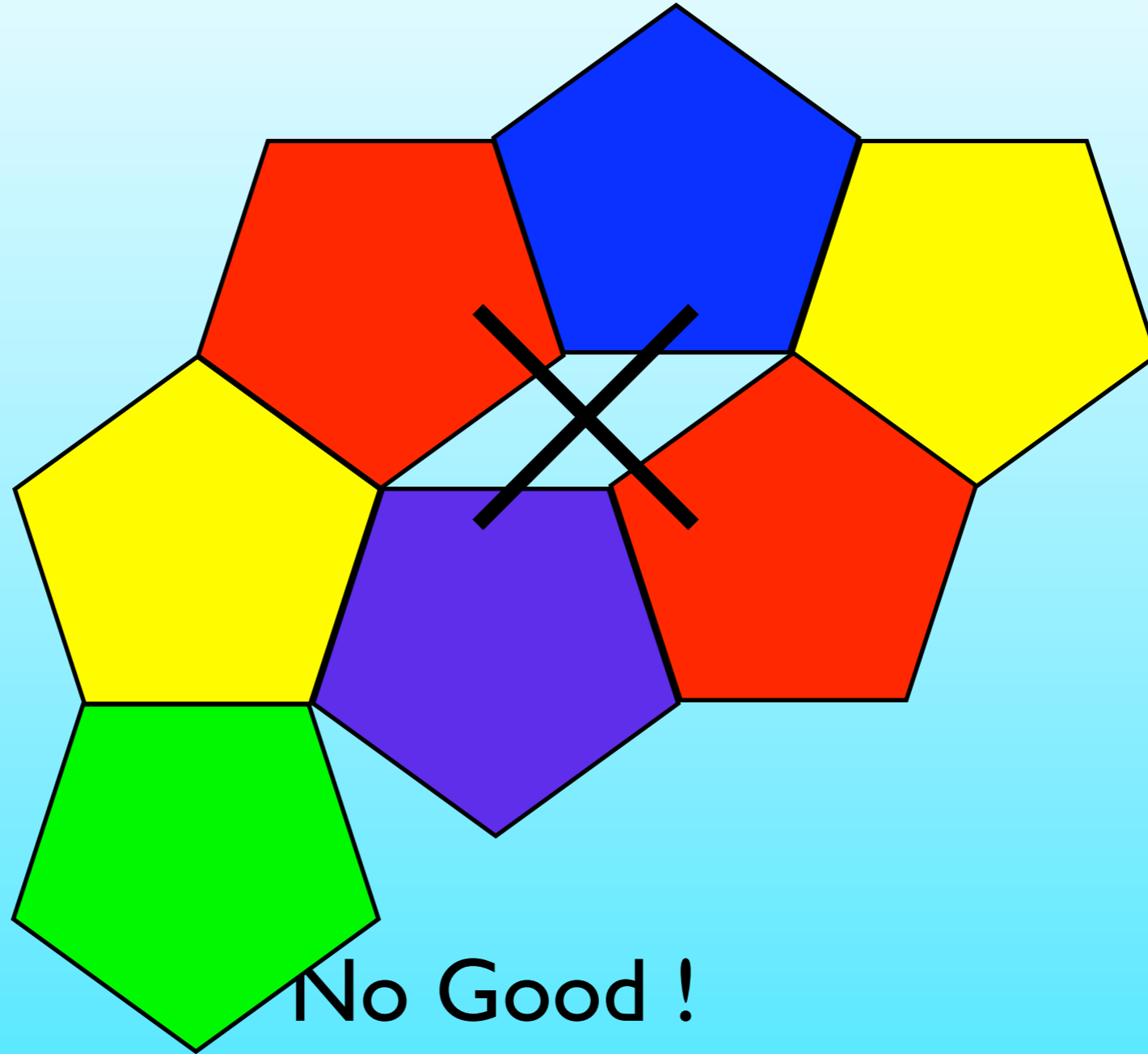
OK

# 回転対称性と空間の埋め尽くし



OK

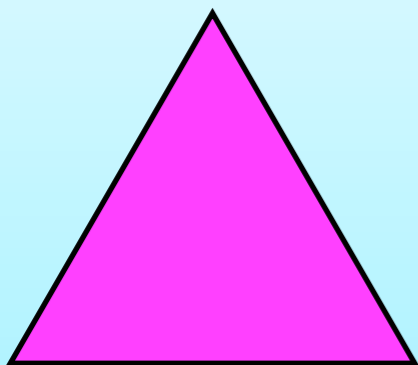
# 回転対称性と空間の埋め尽くし



No Good !  
Impossible !

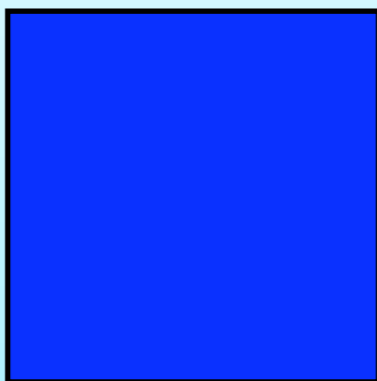
# 回転対称性と空間の埋め尽くし

3



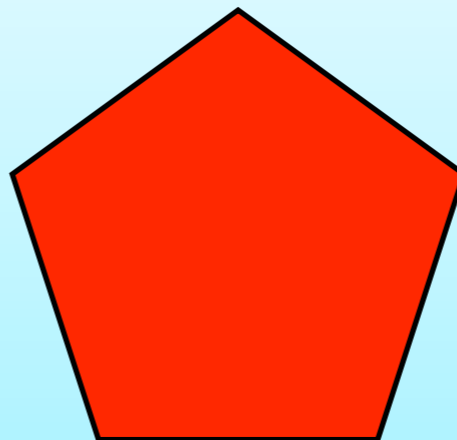
OK!

4



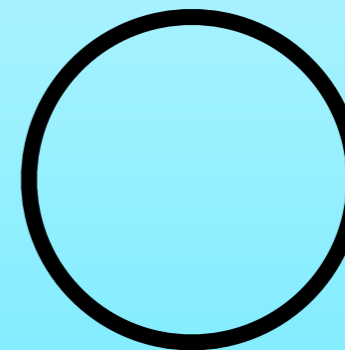
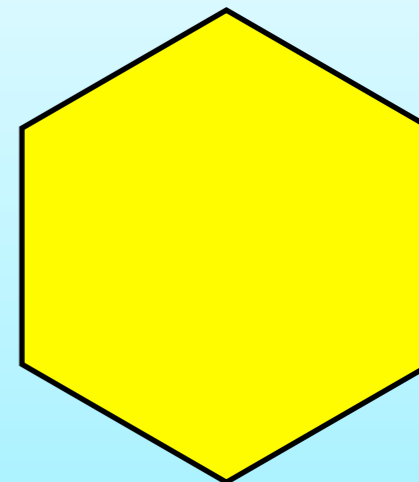
OK!

5



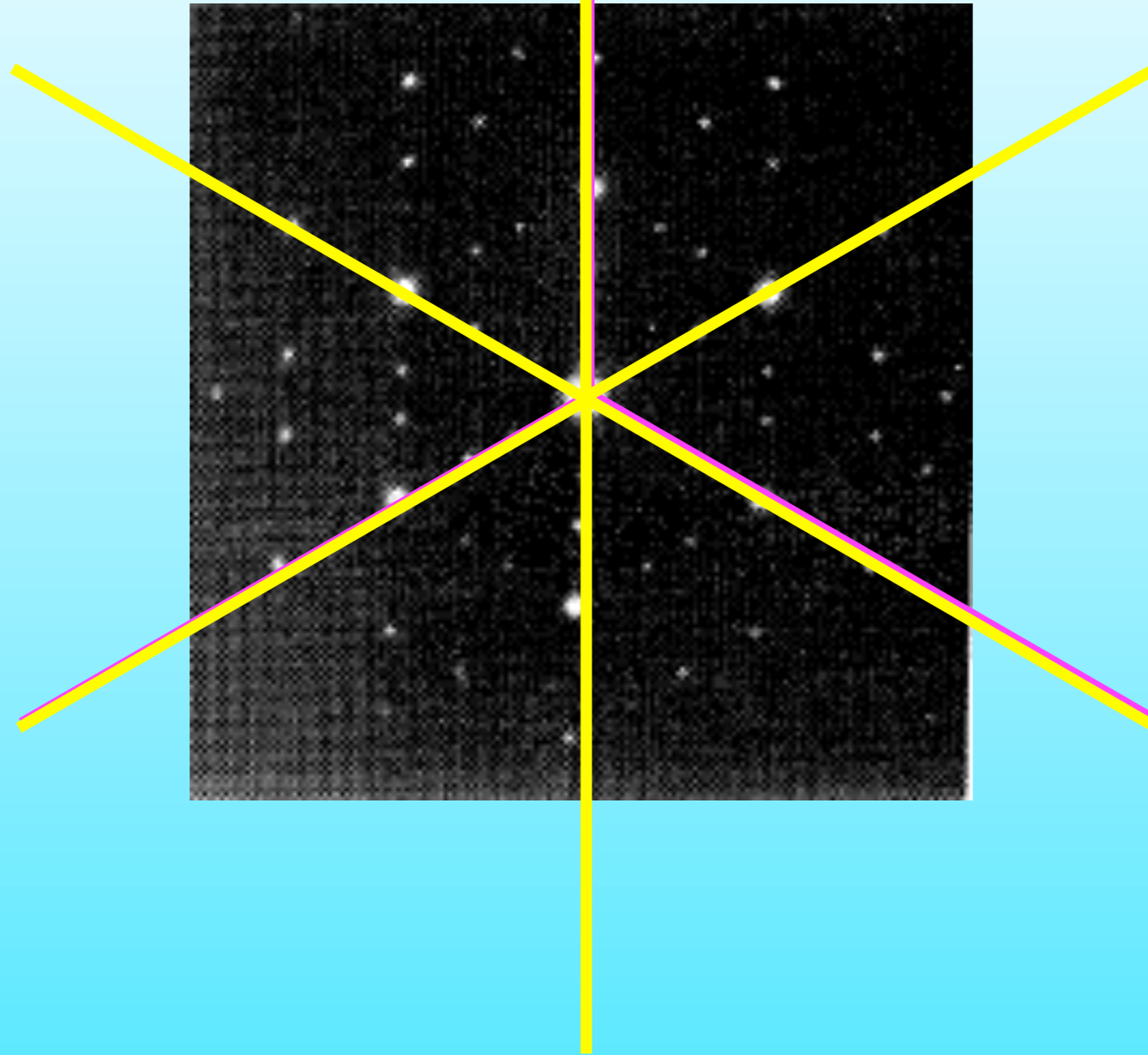
No Good!  
Impossible!

6



OK!

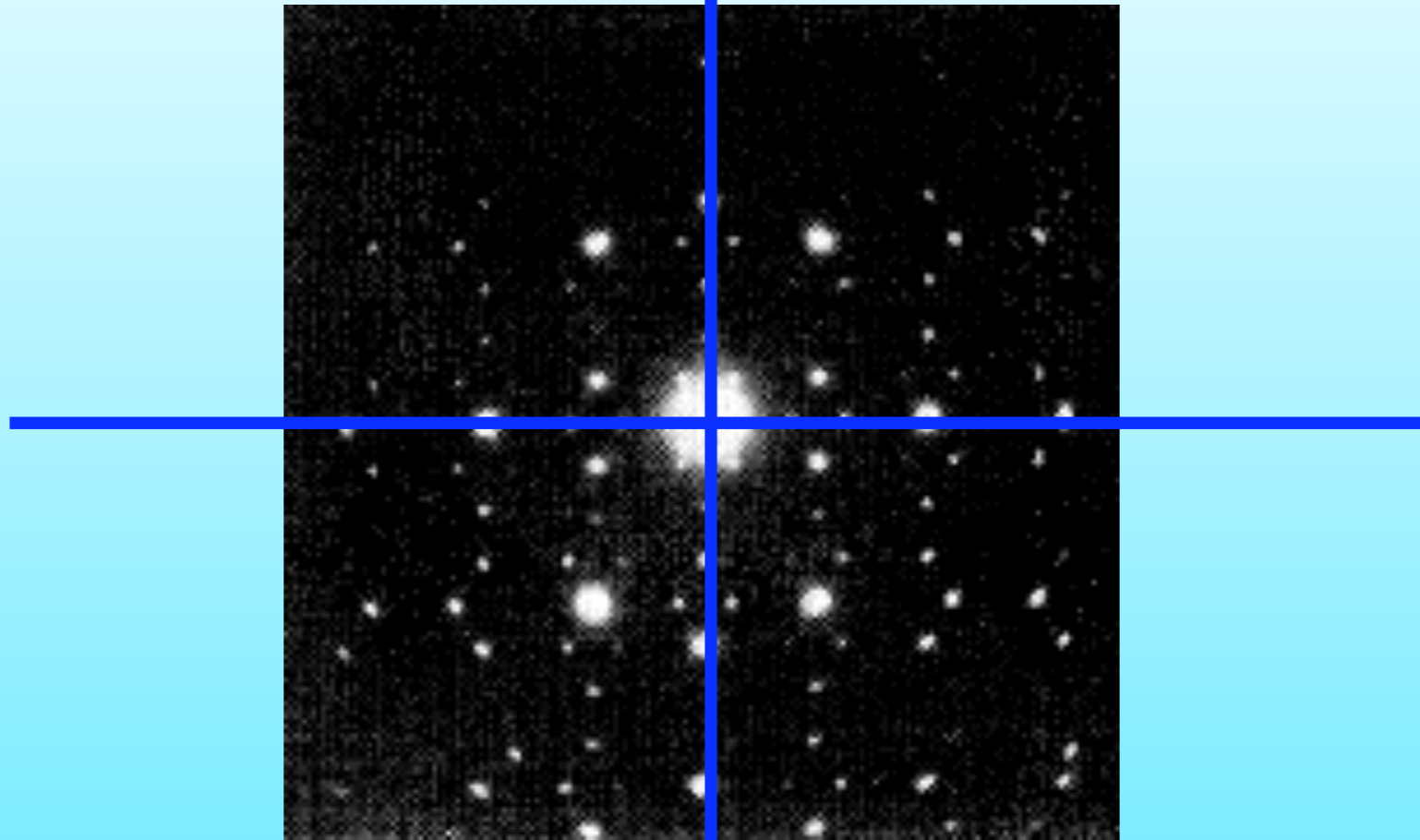
# Discovery of diffraction pattern with 5 fold symmetry



3

6

# Discovery of diffraction pattern with 5 fold symmetry

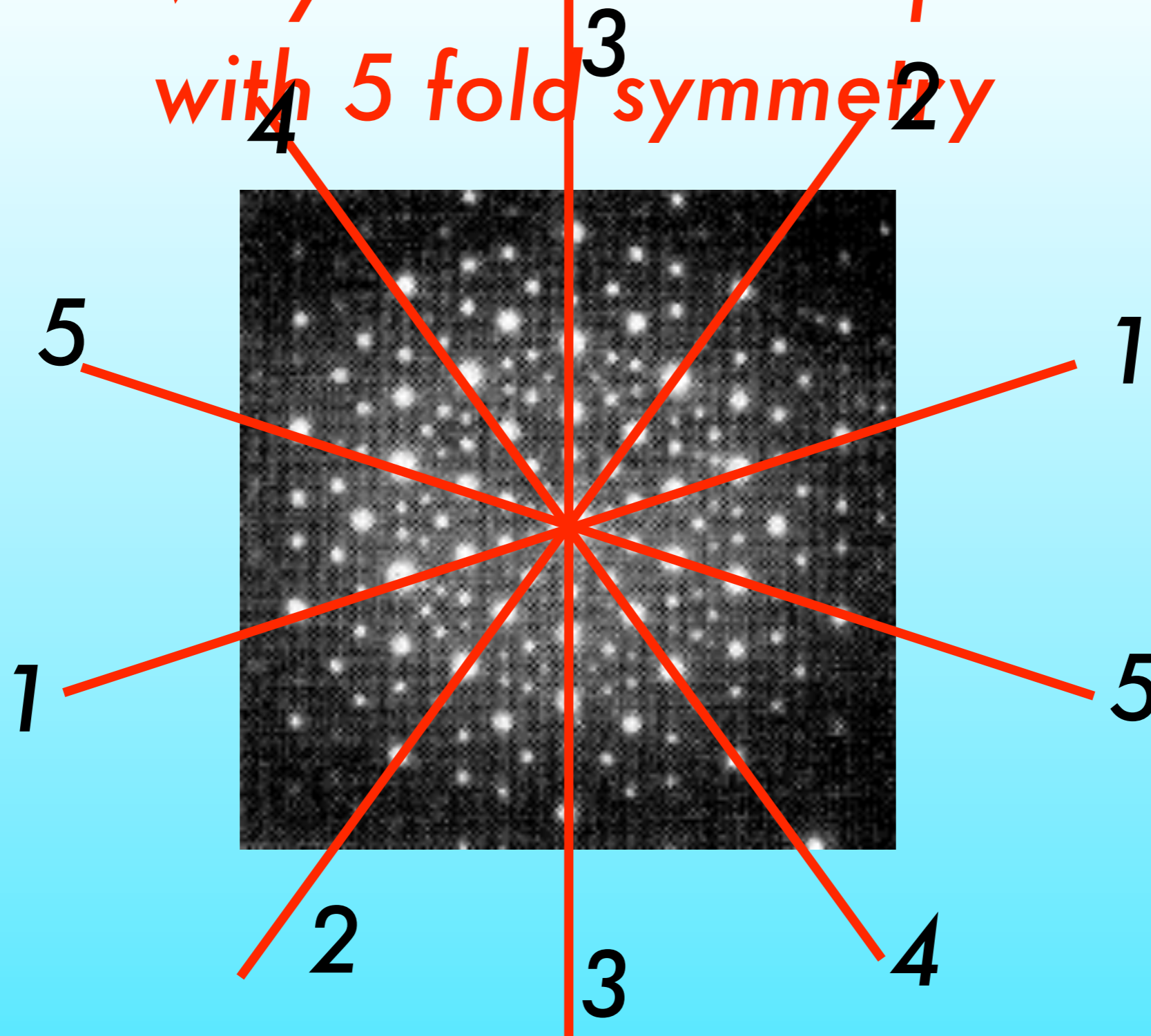


3

4

6

# Discovery of diffraction pattern with 5 fold symmetry



*Should be aperiodic !*

5

VOLUME 53, NUMBER 20

PHYSICAL REVIEW LETTERS

12 NOVEMBER 1984

**Metallic Phase with Long-Range Orientational Order and No Translational Symmetry**

D. Shechtman and I. Blech

*Department of Materials Engineering, Israel Institute of Technology–Technion, 3200 Haifa, Israel*

and

D. Gratias

*Centre d'Etudes de Chimie Métallurgique, Centre National de la Recherche Scientifique, F-94400 Vitry, France*

and

J. W. Cahn

*Center for Materials Science, National Bureau of Standards, Gaithersburg, Maryland 20760*

(Received 9 October 1984)

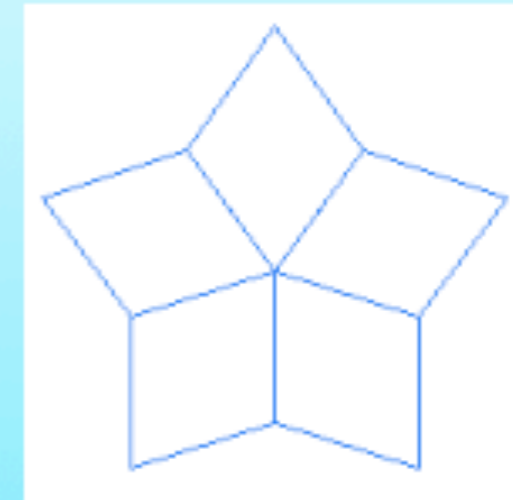
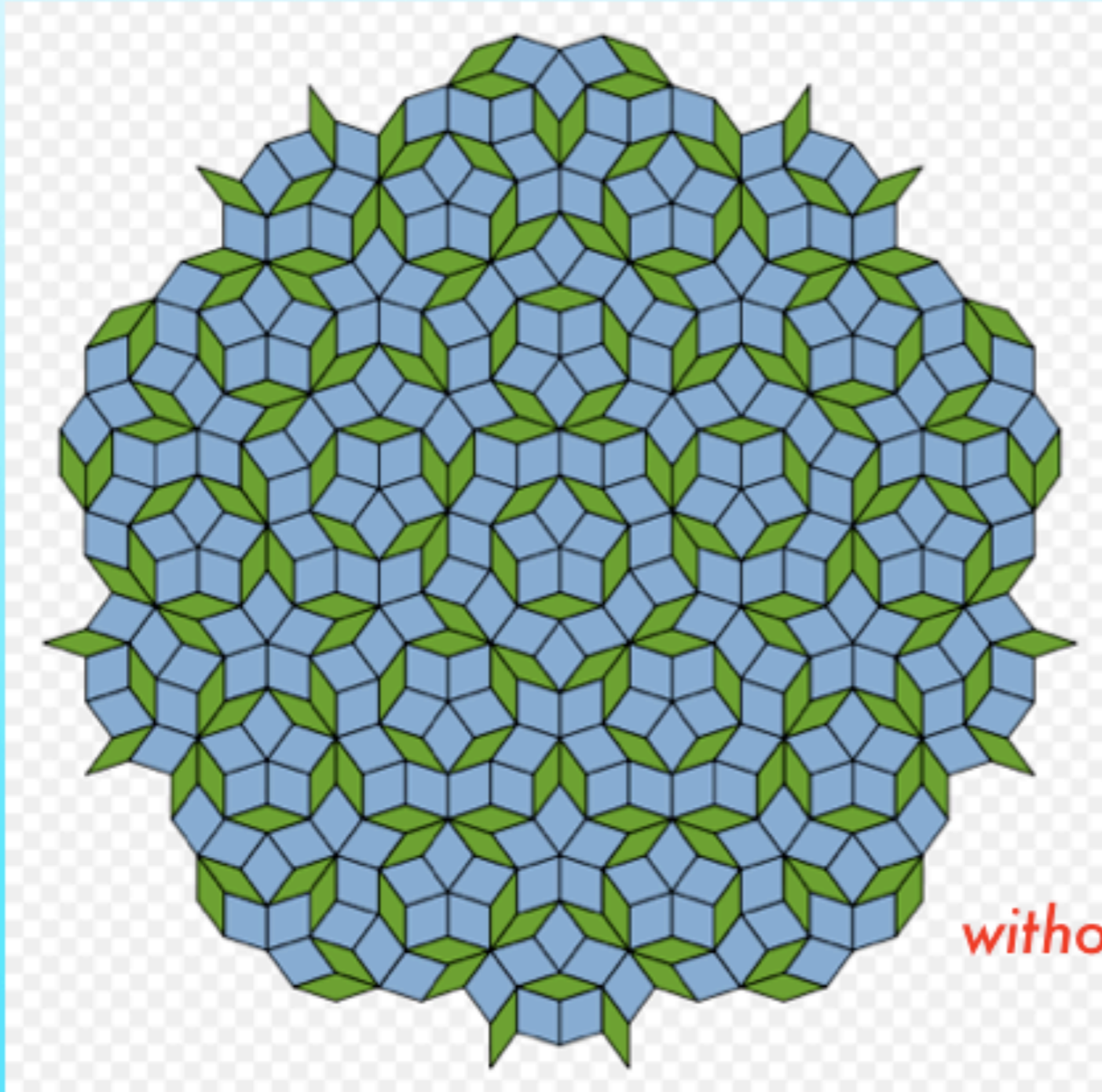
We have observed a metallic solid (Al–14-at.-%-Mn) with long-range orientational order, but with icosahedral point group symmetry, which is inconsistent with lattice translations. Its diffraction spots are as sharp as those of crystals but cannot be indexed to any Bravais lattice. The solid is metastable and forms from the melt by a first-order transition.

**QUASICRYSTAL**

**準結晶**



# Model of the Quasi-crystal Penrose tiling



*5 fold symmetry  
without translational invariance*

[http://upload.wikimedia.org/wikipedia/commons/8/8e/Penrose\\_tiling.gif](http://upload.wikimedia.org/wikipedia/commons/8/8e/Penrose_tiling.gif)

# 物質中にあるフラクタル、自己相似形な構造

A. ホフスタッターによるフラクタルな蝶

B. 悪魔の階段

C. ペンローズ・タイリング

