Les quasicristaux
Une étrange mosaique d'atomes

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cnrs

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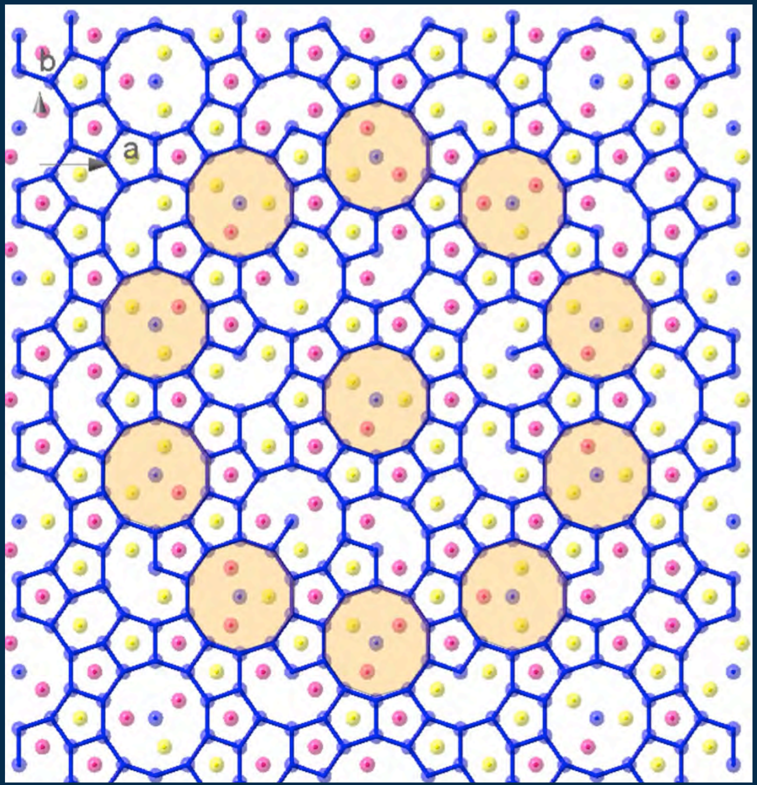
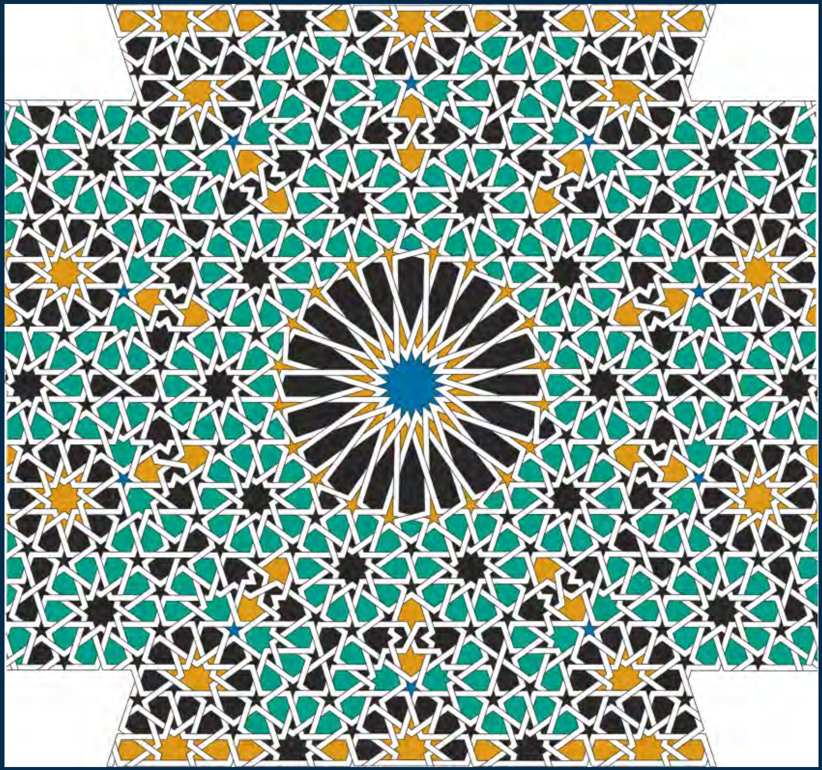
Une étrange mosaique d’atomes

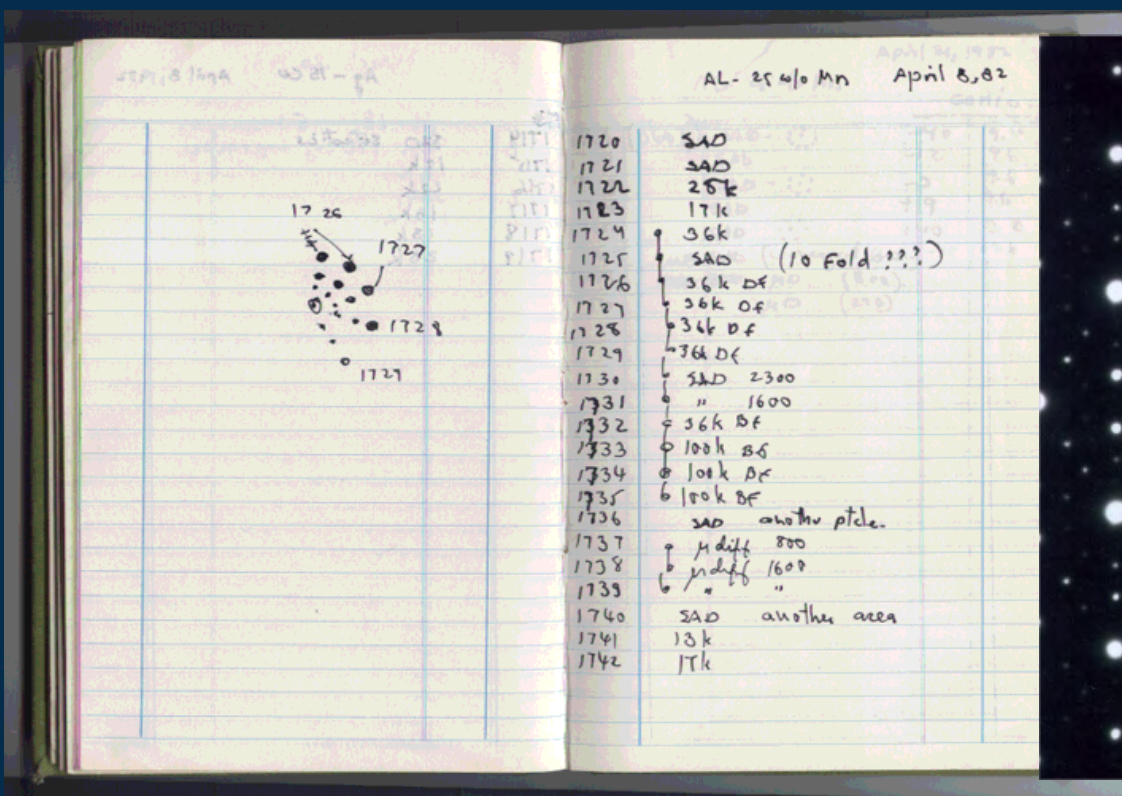




Dan Shechtman. Prix Nobel de Chimie en 2011 ‘pour la découverte des quasicristaux’

La découverte des quasicristaux

En 1982 Dan Shechtman observe ce cliché de diffraction ‘impossible.’



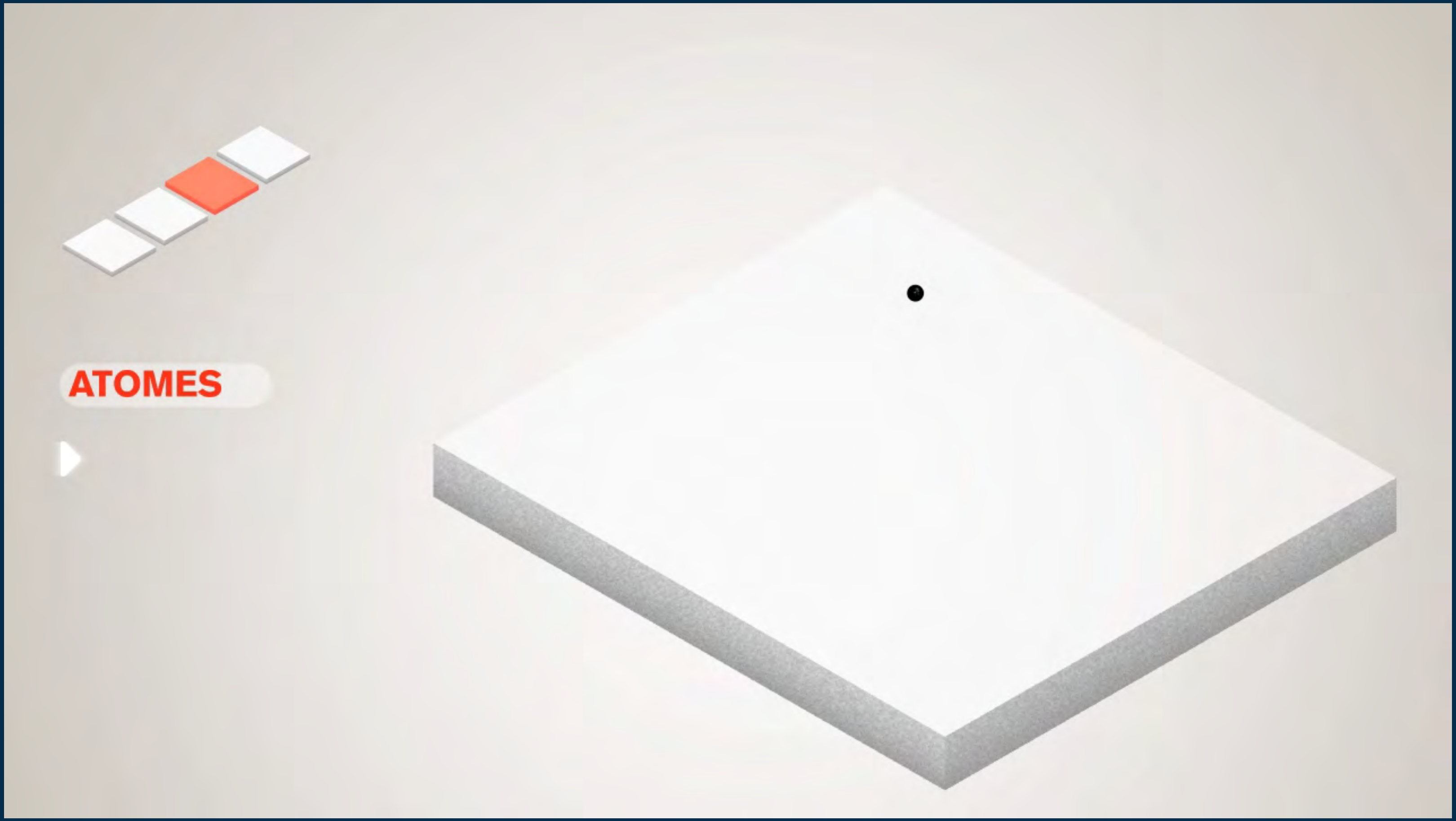
Les ‘règles’ de la cristallographie

- Une structure ordonnée est périodique: cristal : empilement périodique d’atomes
- Seules les symétries d’ordre 2-, 3-, 4- et 6- sont permises.

La cristallographie: une science au coeur de la matière

- L’observation de Dan Shechtman remet en cause deux siècles de cristallographie.
- Organisation des atomes et symétrie.
- Les échelles de l’infiniment petit
- Qu’est ce qu’un atome?

L’atome: taille 0.2 nm



Taille de l’atome: 0.2 nm

réalisation Data-Burger, conseiller scientifique: J. Bobroff - www.toutestquantique.fr

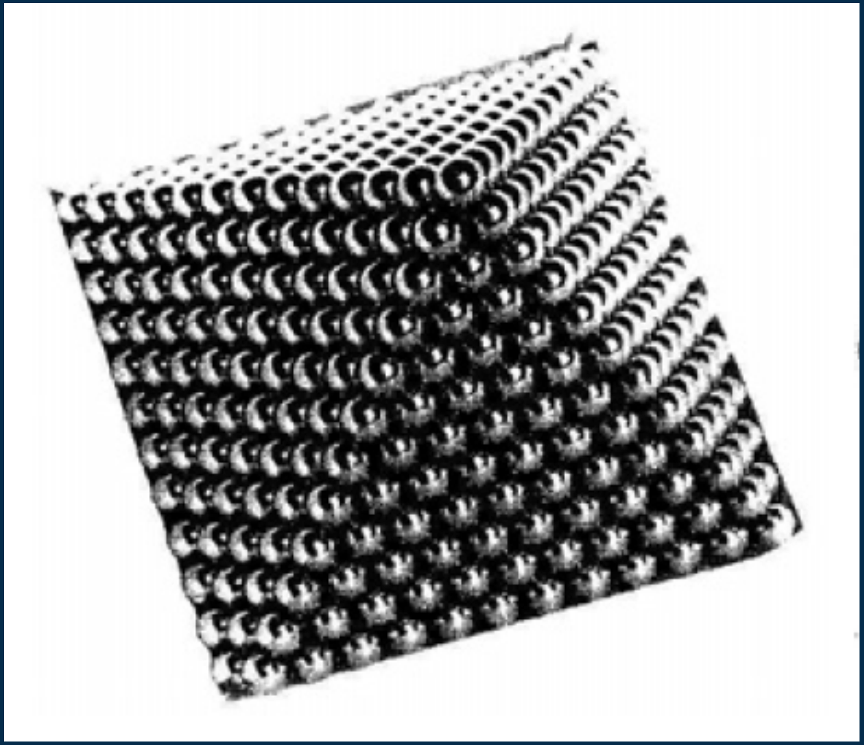
L’atome

Atome
0.2 nm

Molécules

Gaz et liquide

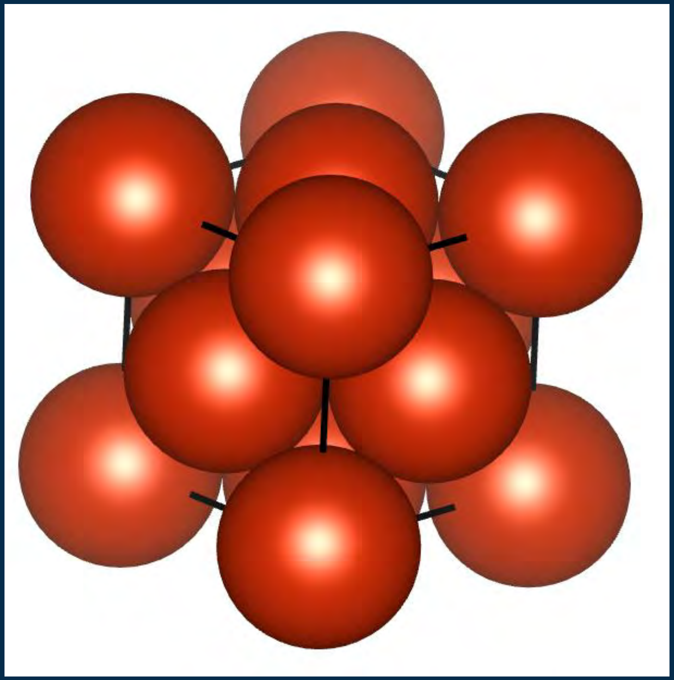
Solide
Cristal et amorphe (liquide gelé)

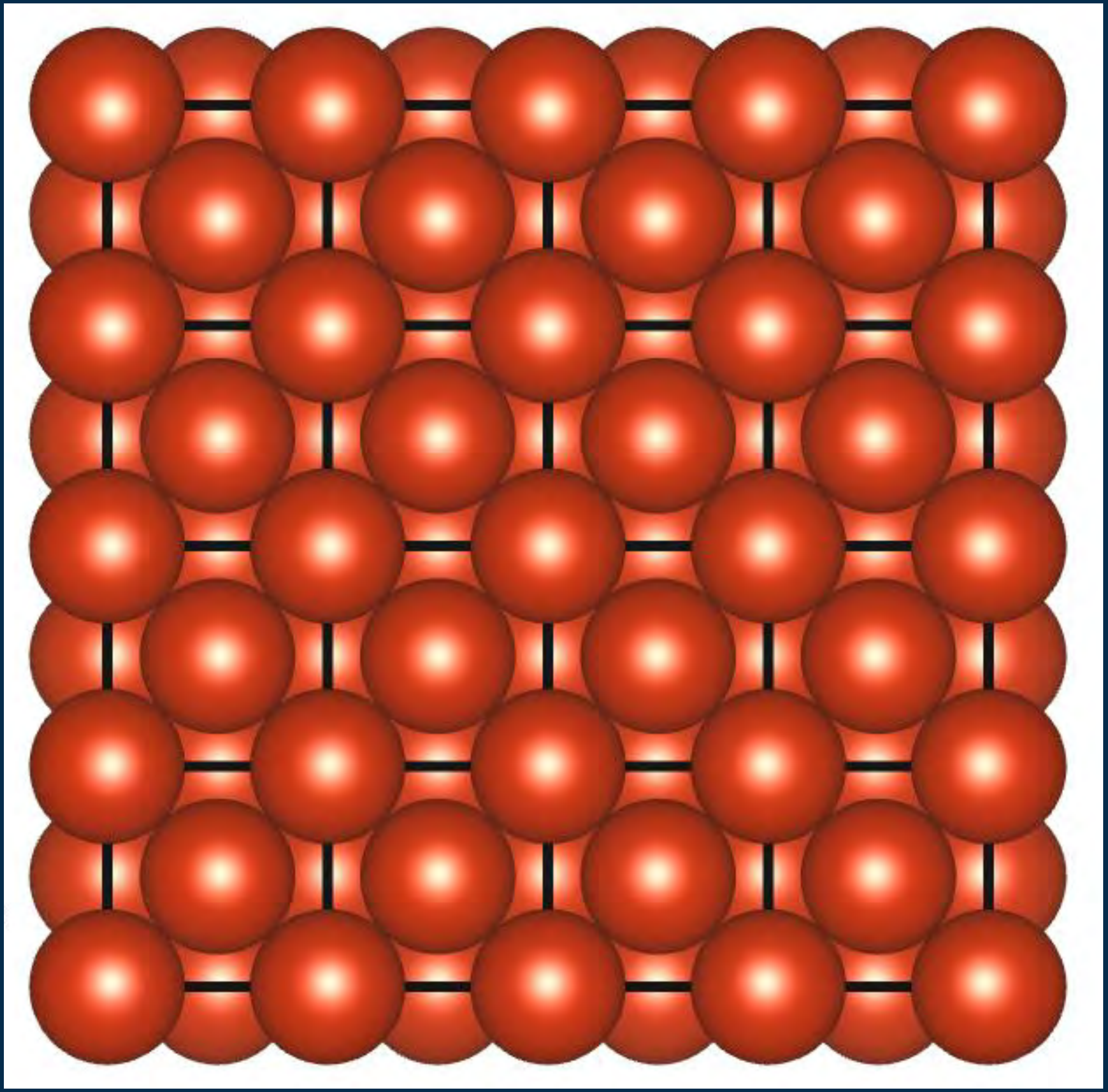


Les atomes au cœur de la matière

Le relief de l'invisible (P.O. Levy, G. Turkieh, J.M. Sanchez)

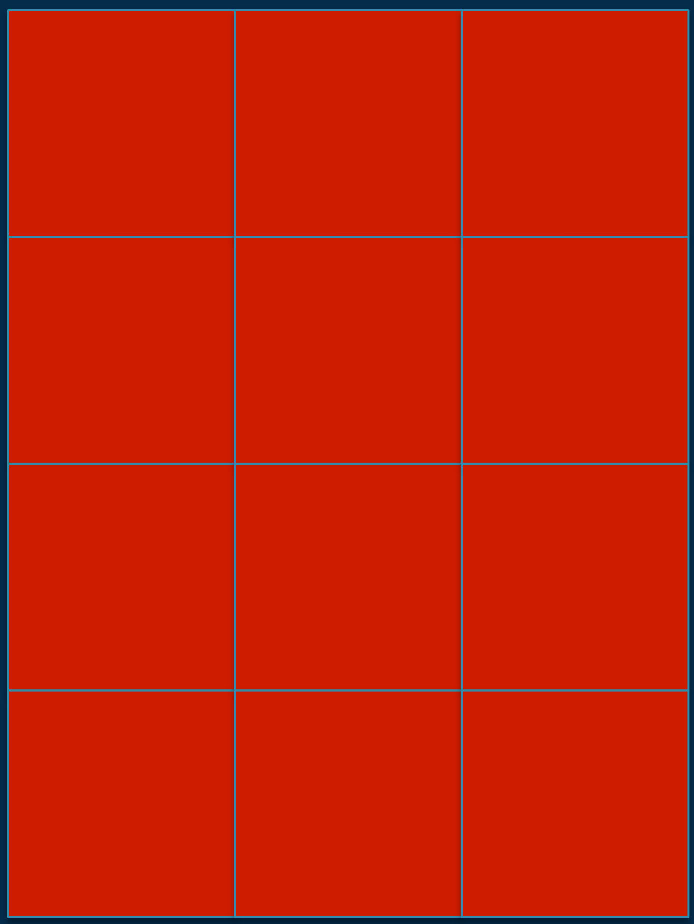
Cristal : Symétrie et périodicité





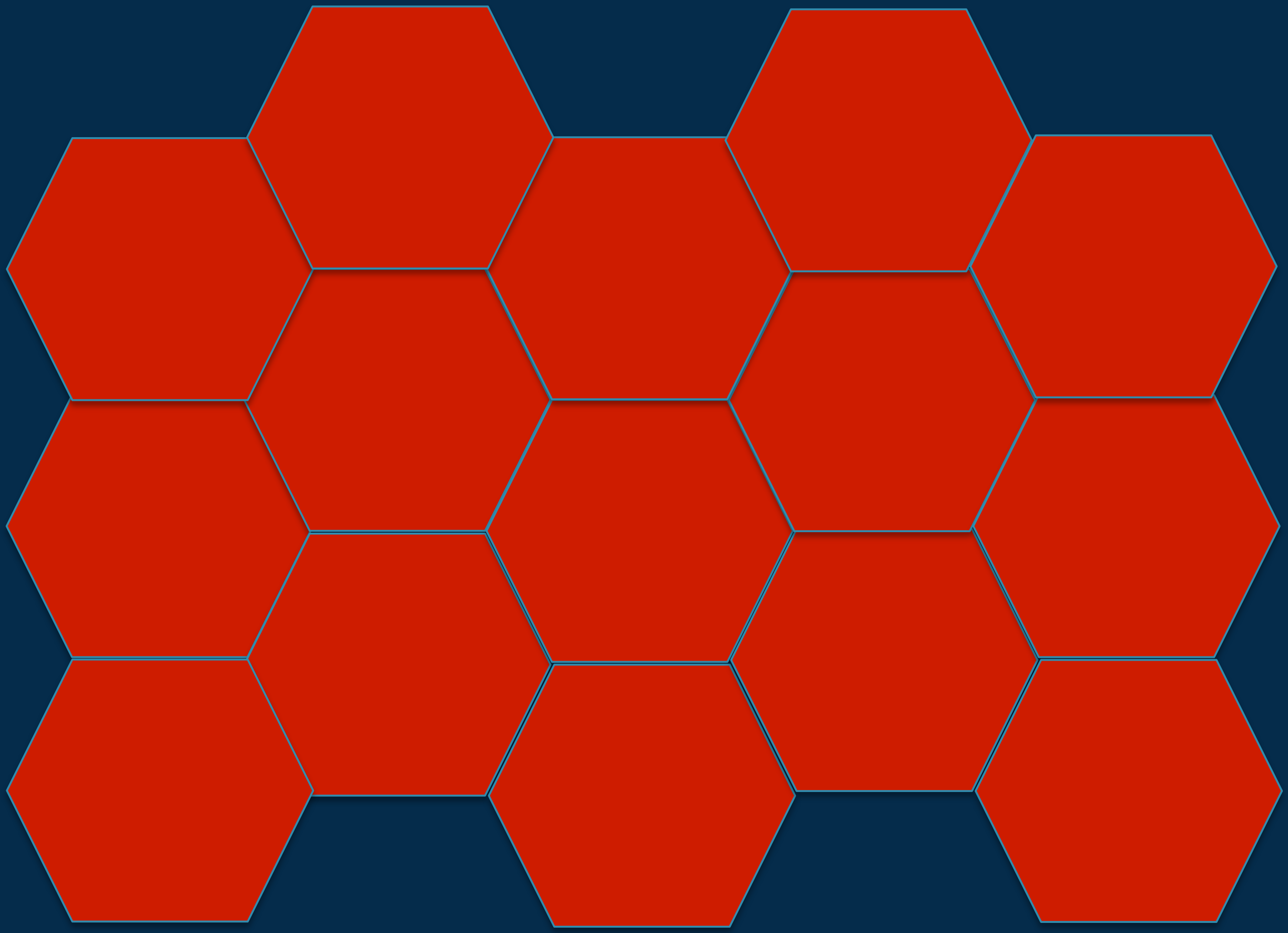
Cristal : Symétrie et périodicité

La symétrie 4 est compatible avec la périodicité



Cristal : Symétrie et périodicité

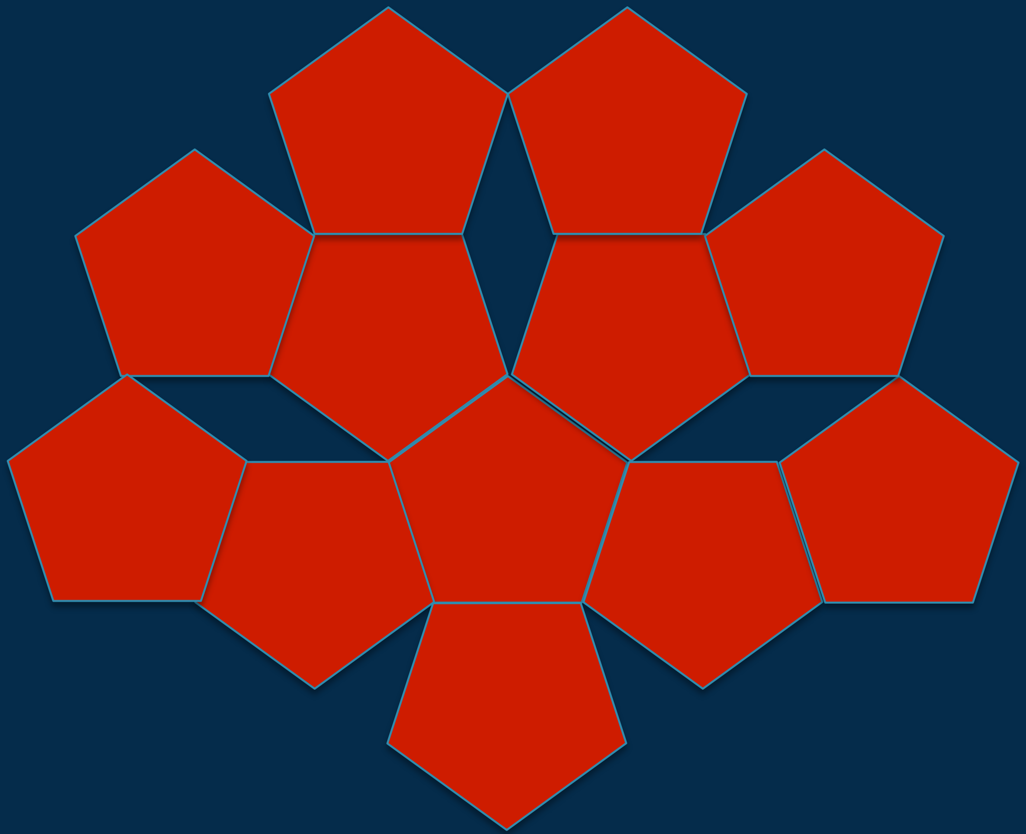
La symétrie 6 est compatible avec la périodicité



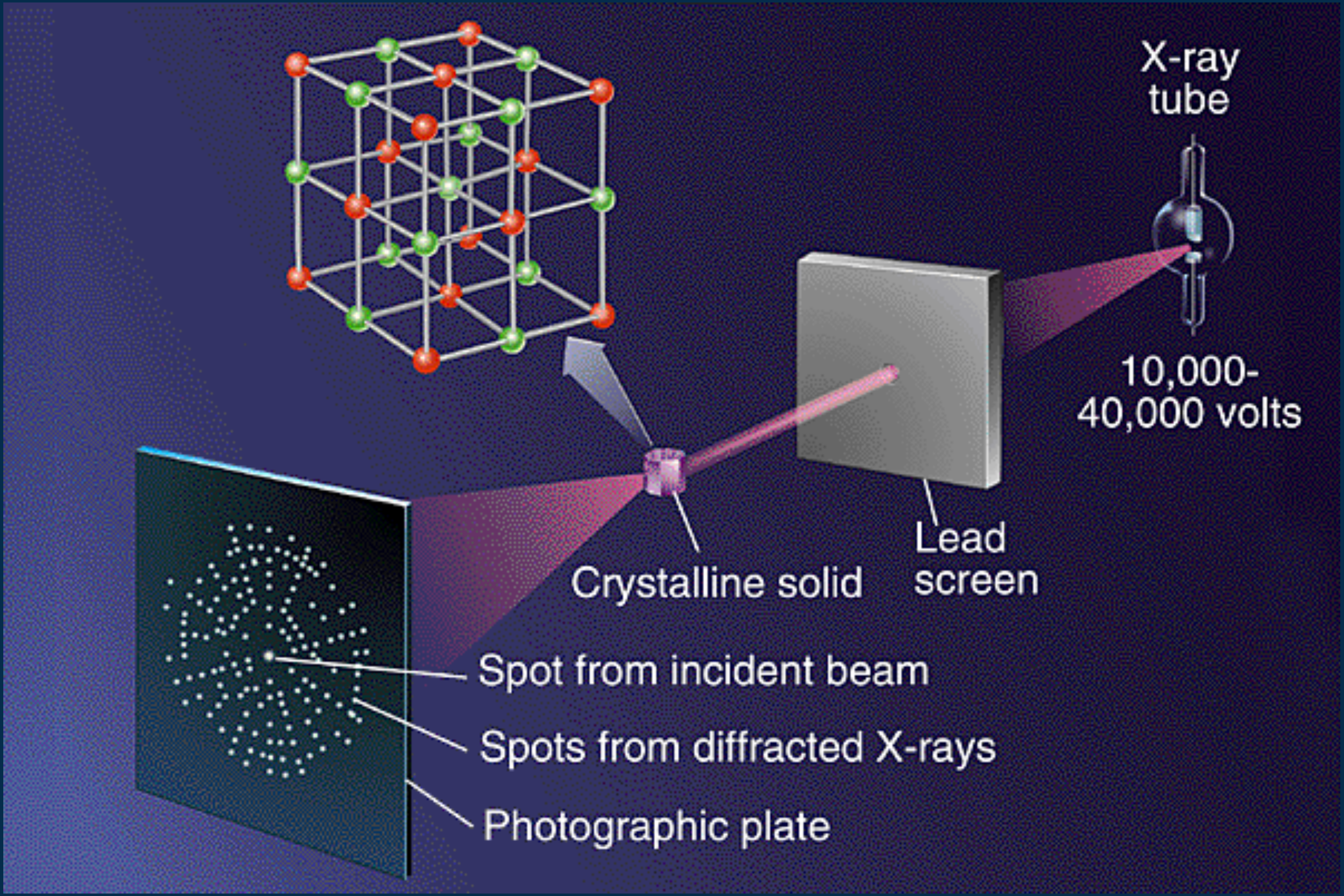
Cristal : Symétrie et périodicité

La symétrie 5 n’est pas compatible avec la périodicité

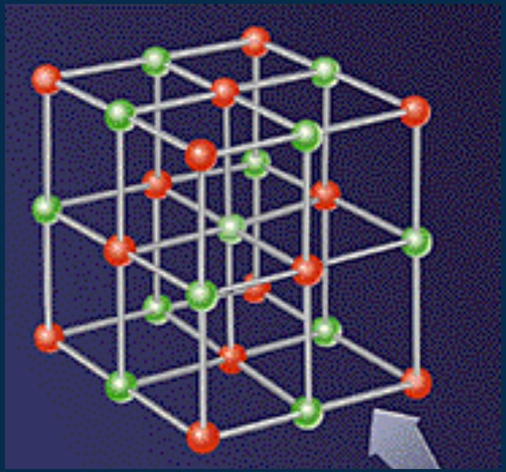
Seulement 2-, 3-, 4- et 6- sont compatibles avec la périodicité.

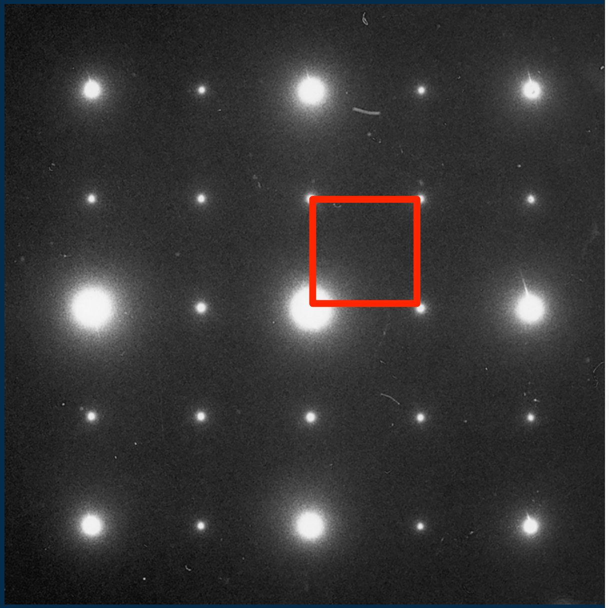


La diffraction

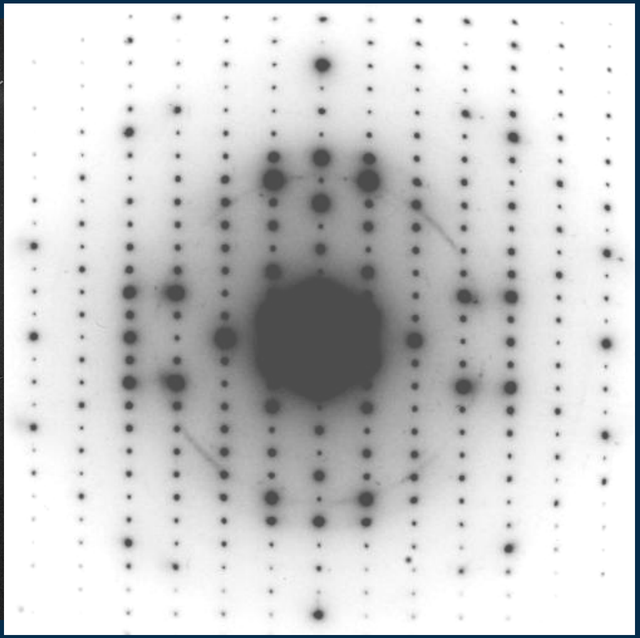


Symétrie et diffraction





Structure simple



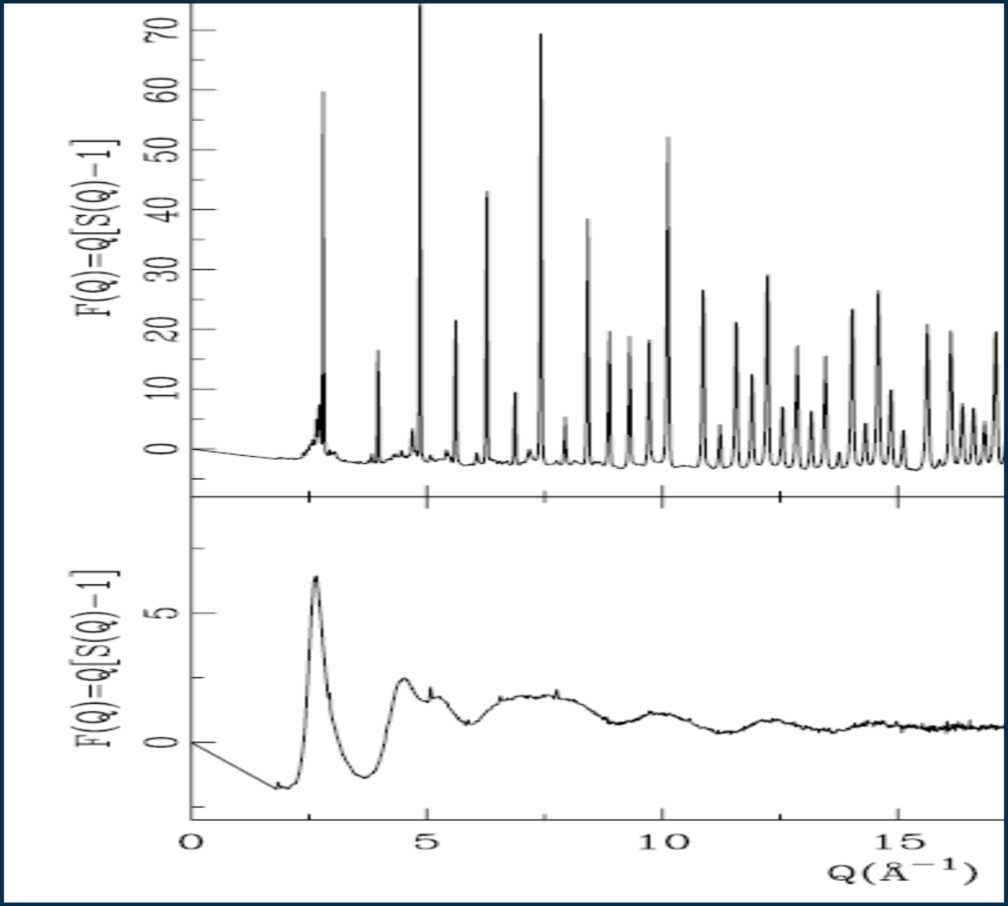
Structure complexe

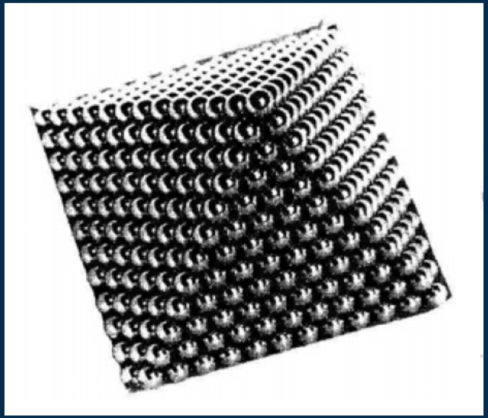
Le diagramme de diffraction reflète la périodicité et la symétrie . 2-, 3- 4- et 6- sont ‘autorisés’ .

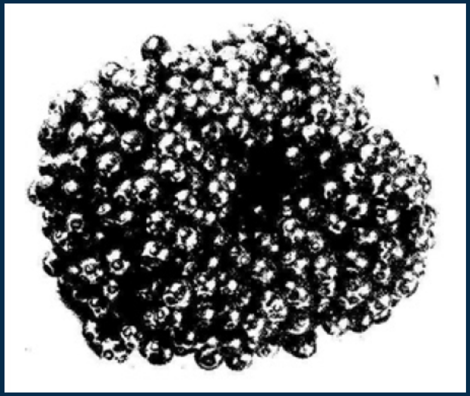
La symétrie d’ordre 5 ou 10 est interdite.

Cristal et amorphe

Cliché de diffraction

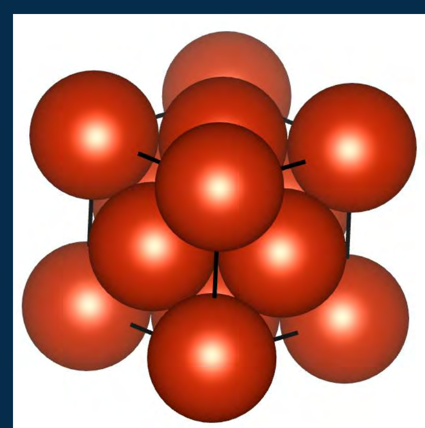


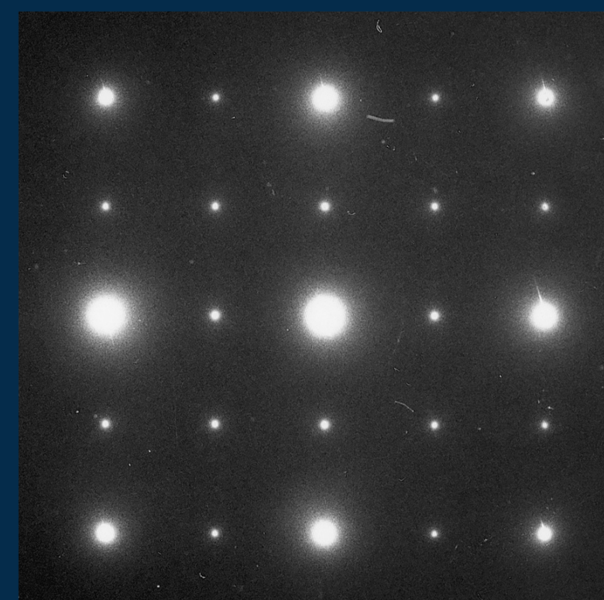




Les ‘règles’ de la cristallographie

- cristal : empilement périodique d’atomes
- Seules les symétries d’ordre 2-, 3-, 4- et 6- sont permises.
- Diffraction : pics et symétrie 2-, 3-, 4-, 6-

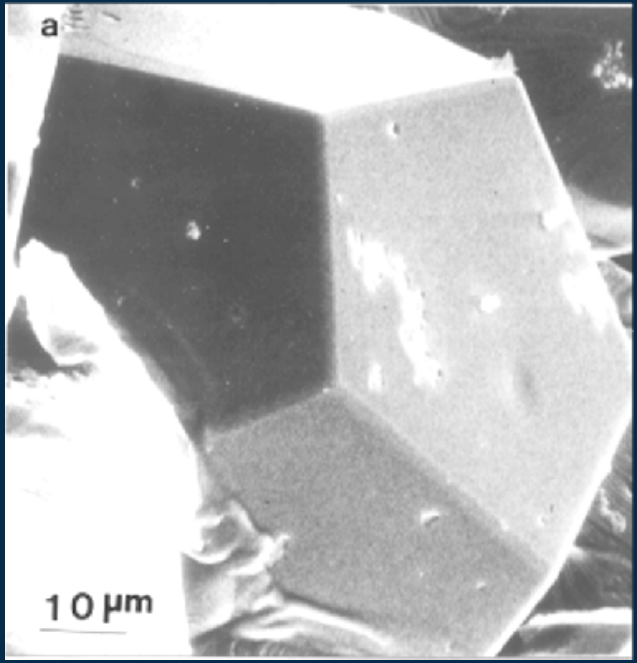




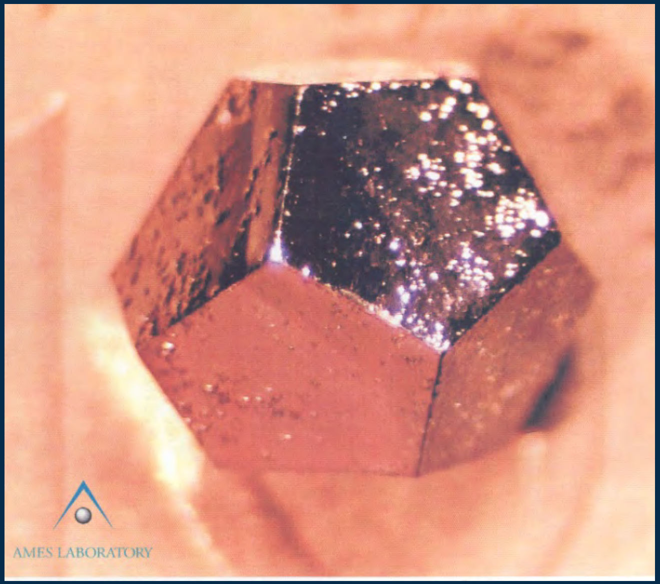
Quasicristal: le cristal impossible

Alliage intermétallique: AlCuFe, AlPdMn

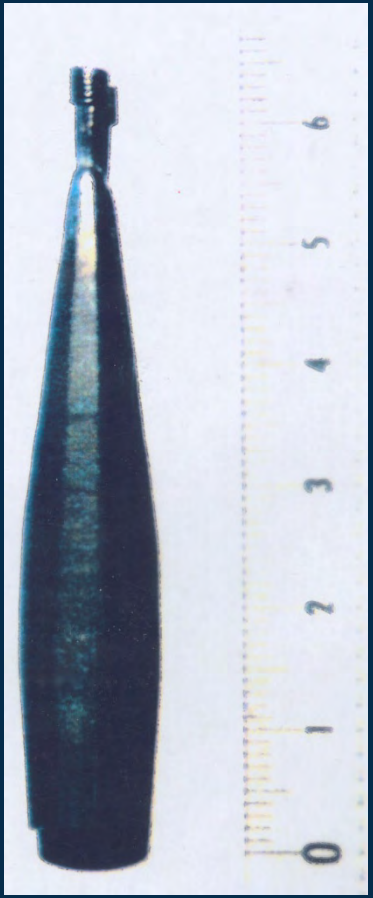
Obtenu par refroidissement lent



i-AlCuFe (from A.P. Tsai)



i-ZnMgY (I. Fisher)



i-AlPdMn (M. Boudard)

Quasicristal: le cristal impossible

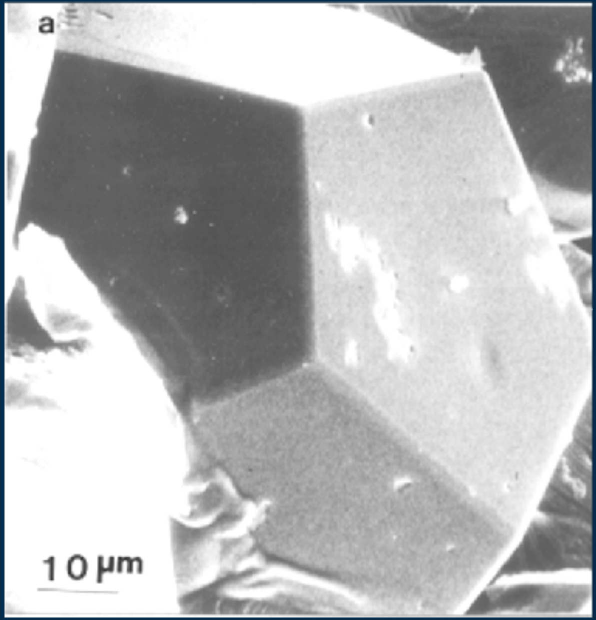
i-AlCuFe

Symetrie 10

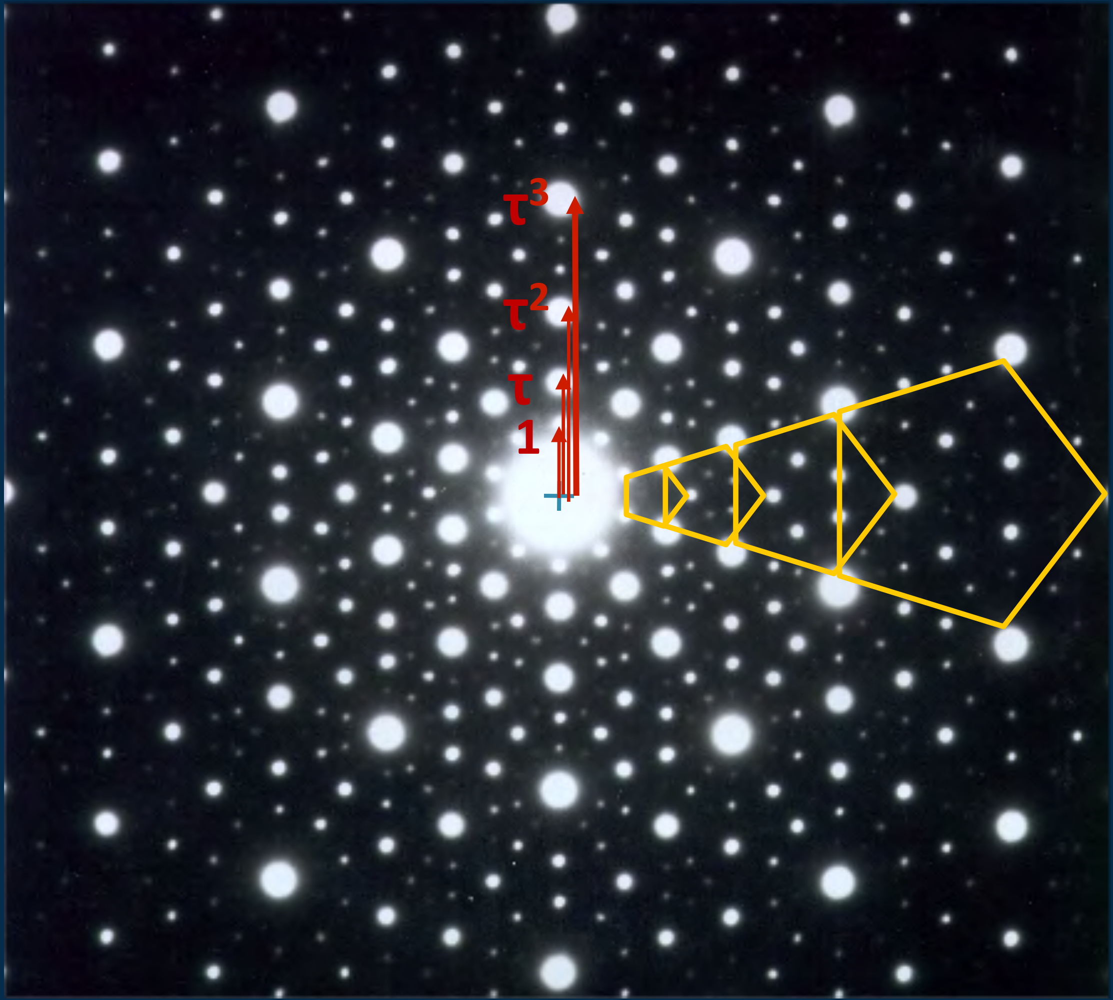
Pics de Bragg

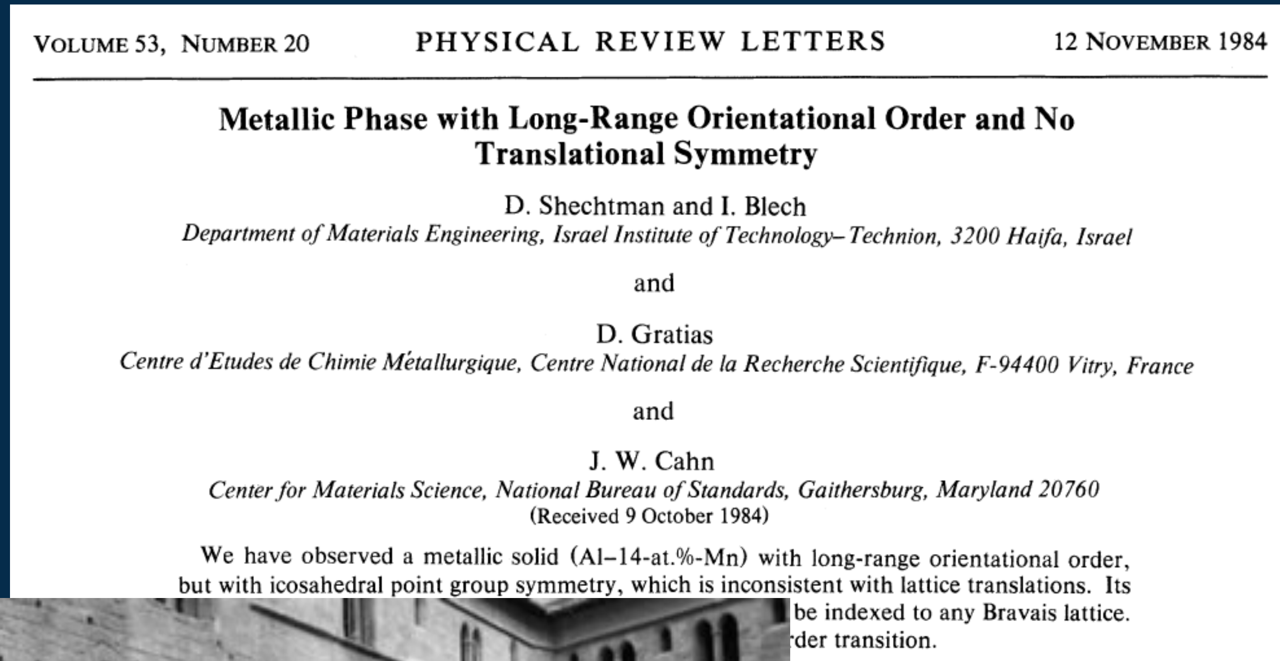
Pas de périodicité

$\tau=(1+\sqrt{5})/2=1.618$



(from A.P. Tsai)





VOLUME 53, NUMBER 20 PHYSICAL REVIEW LETTERS 12 NOVEMBER 1984

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

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and

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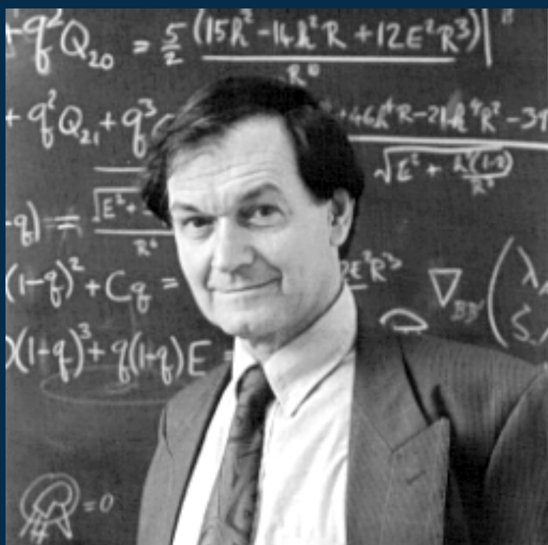
and

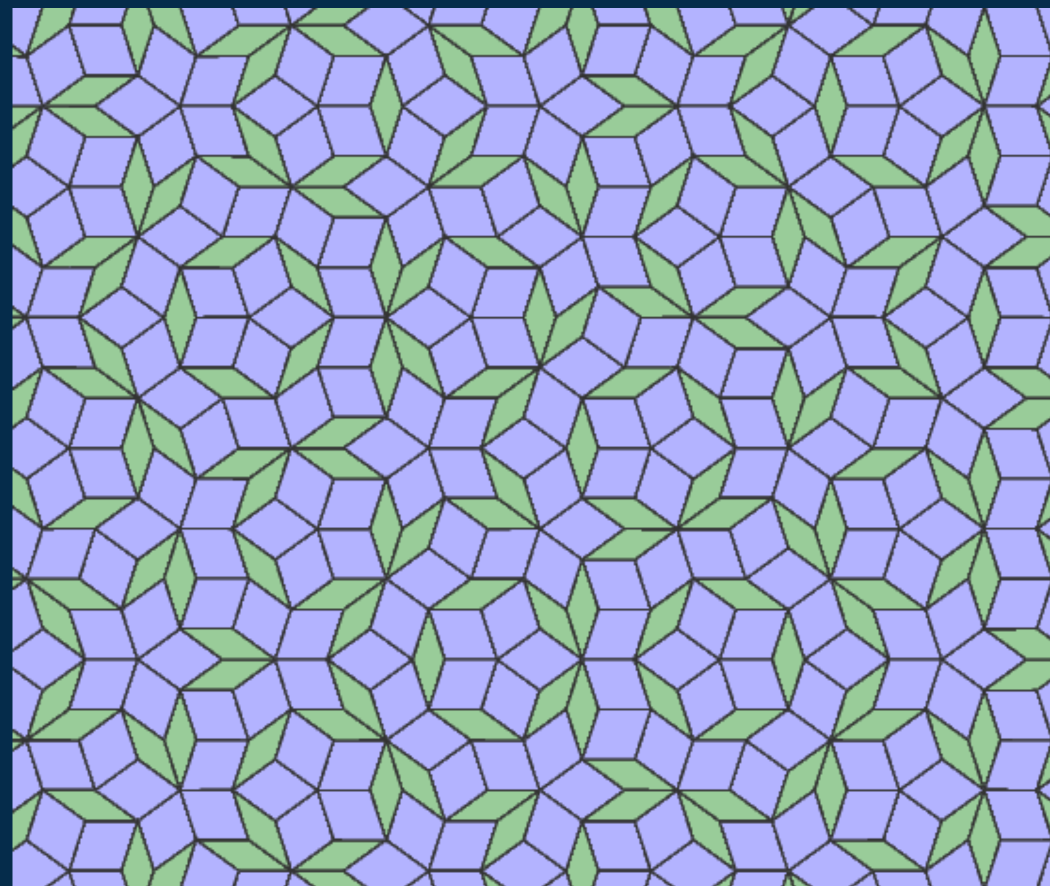
J. W. Cahn
Center for Materials Science, National Bureau of Standards, Gaithersburg, Maryland 20760
(Received 9 October 1984)

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 ... be indexed to any Bravais lattice. ...rder transition.

Les 4 découvreurs des quasicristaux. (From J.M. Dubois), 1995)

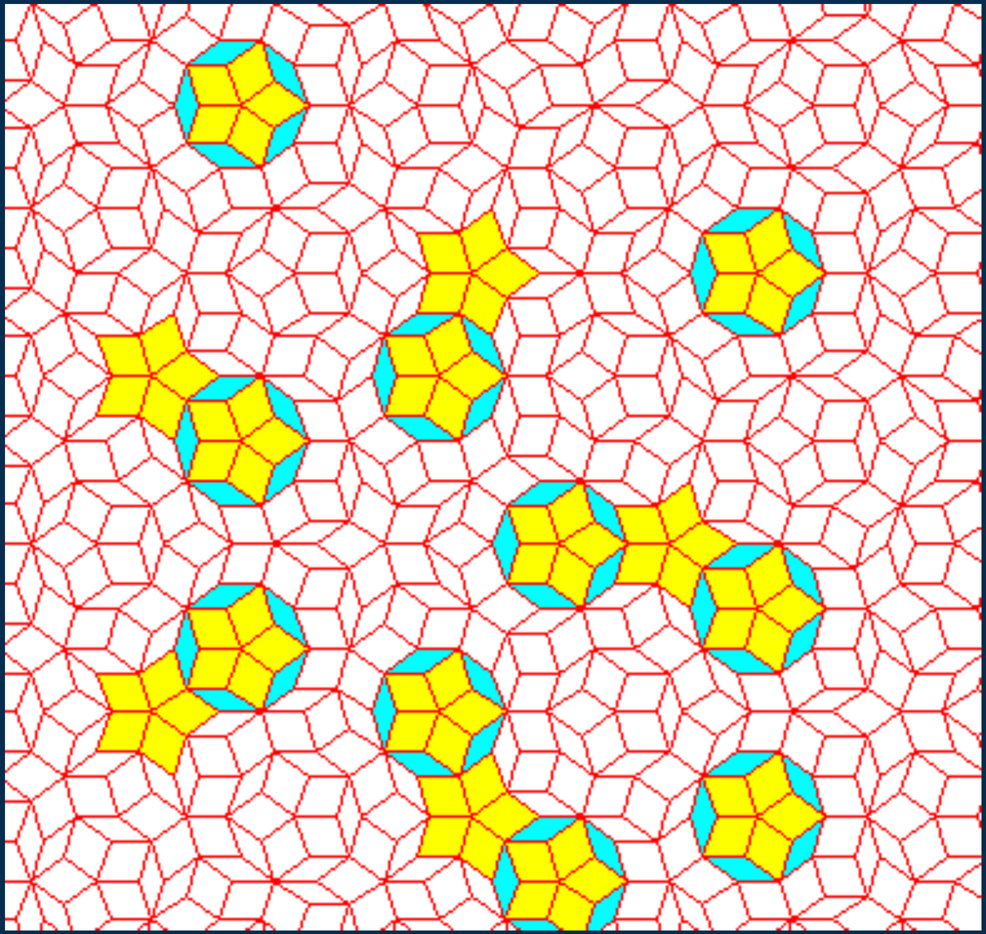
Le pavage de Penrose (1974)





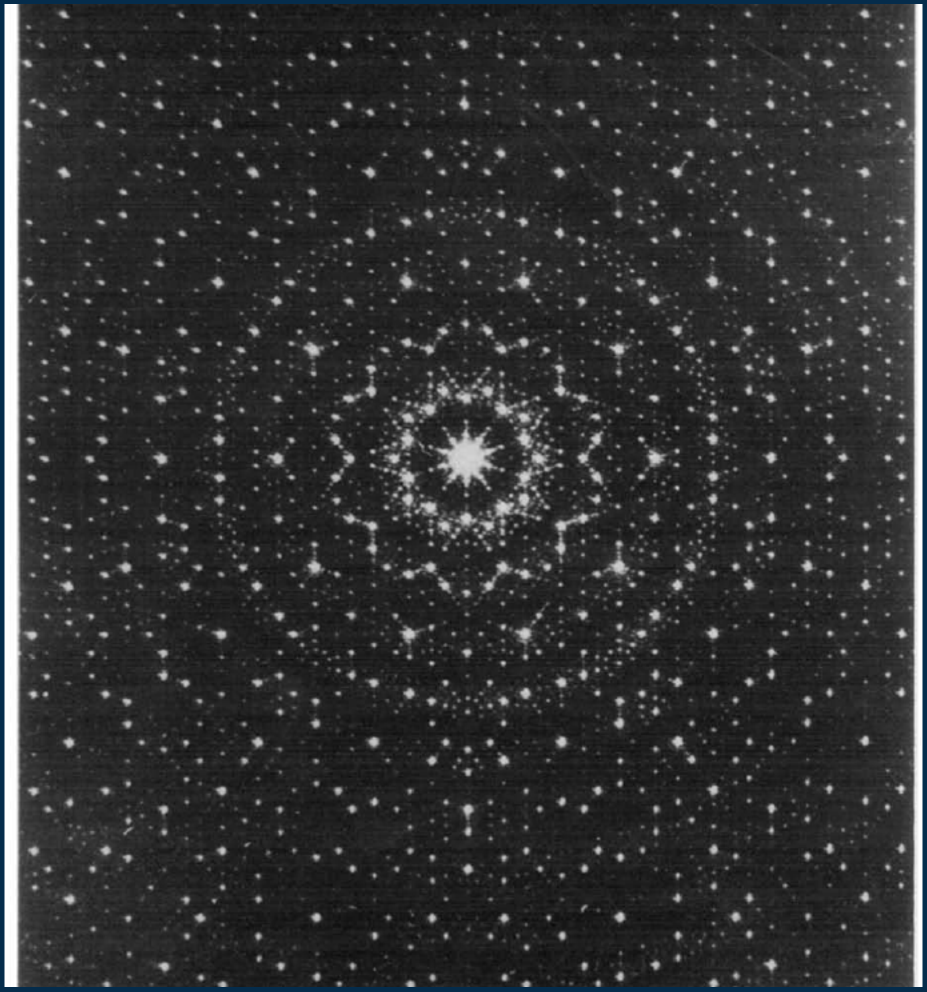
Non périodique MAIS ordonné.

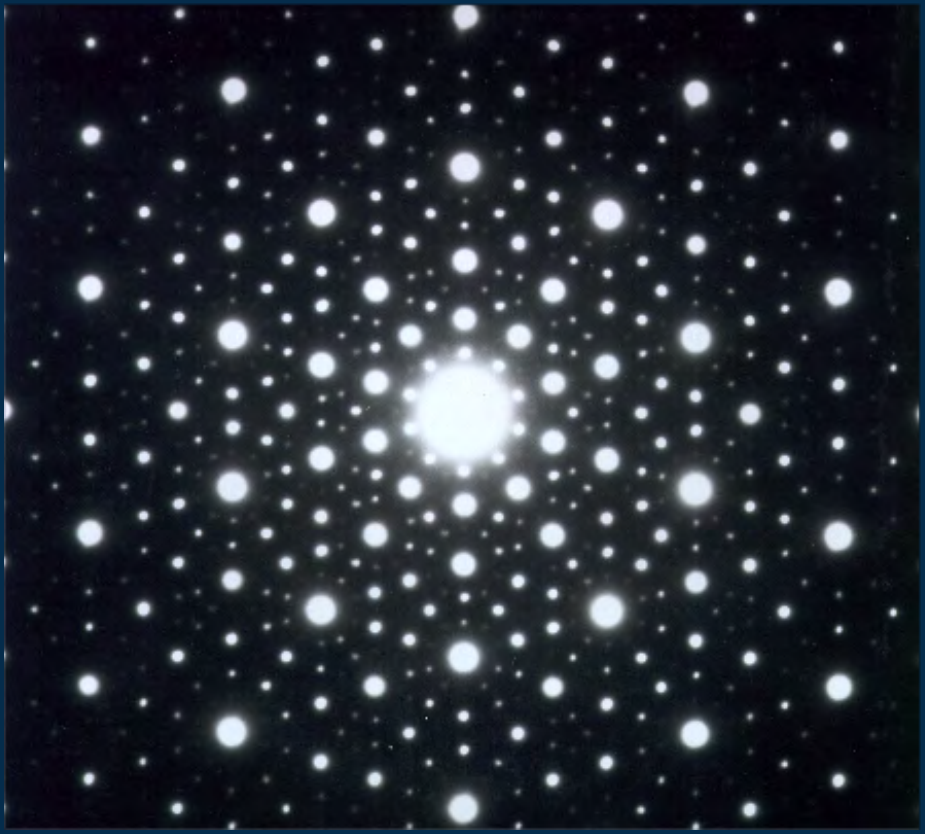
Pavage de Penrose



Ordonné, symétrie 5 localement.

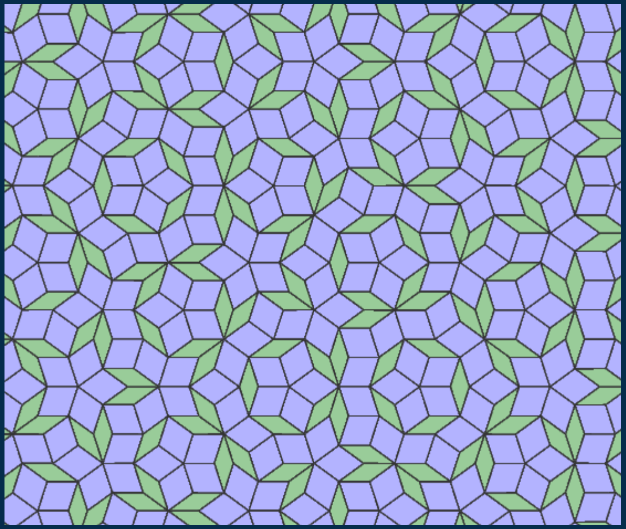
Diffraction du pavage de Penrose (Alan Mackay)

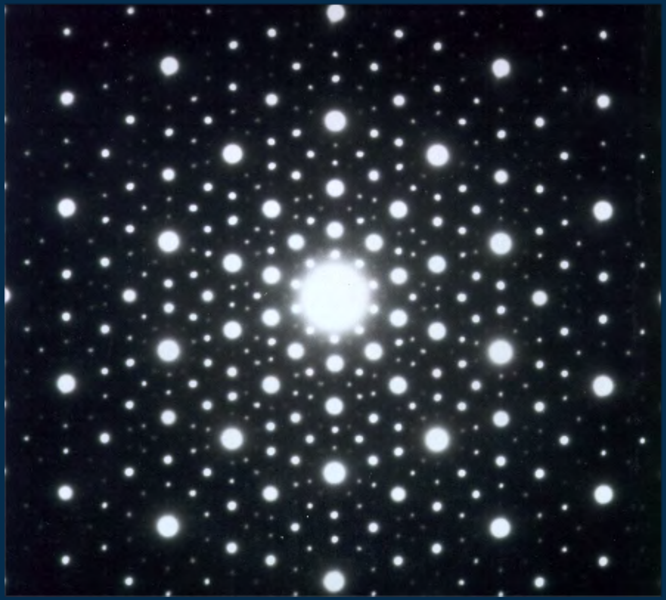




‘L’erreur’ de la cristallographie

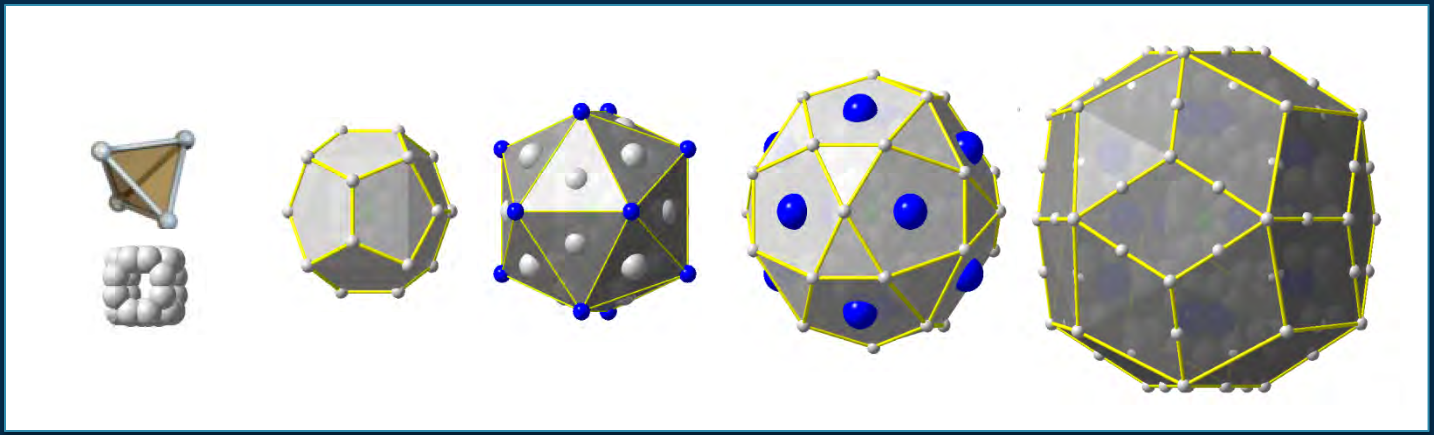
- ORDRE egal PERIODICITE est faux
- Le quasicristal: un nouveau type d’ordre avec la symétrie 5
- Le cristal redéfinit



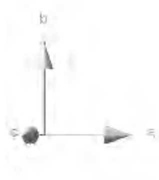


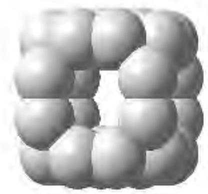
Struture du quasicristal i-CdYb

Empilement quasipériodique d’amas



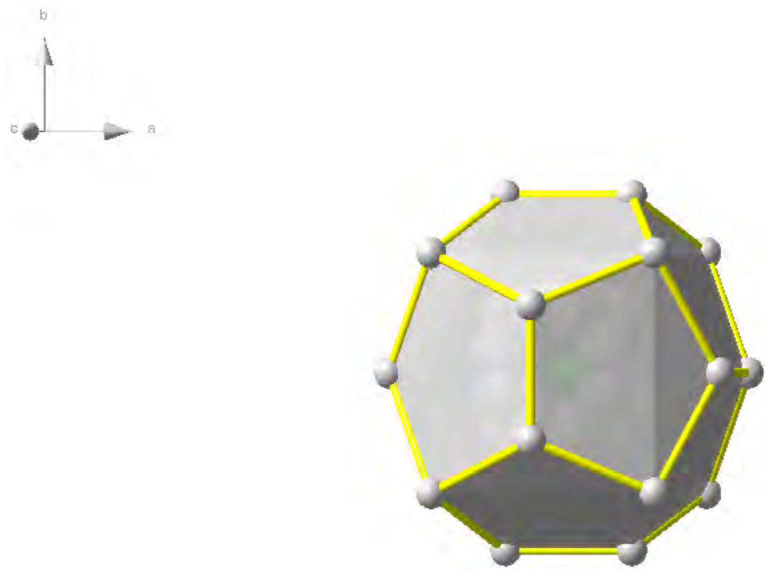
Amas atomique





Tetraèdre de Cd

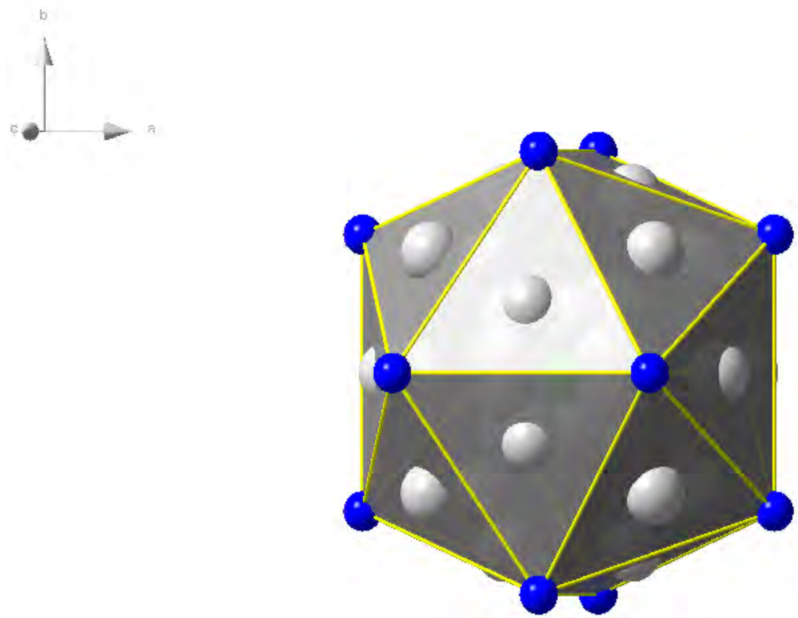
Amas atomique



Dodécaèdre de Cd

R=4.6 Å

Amas atomique

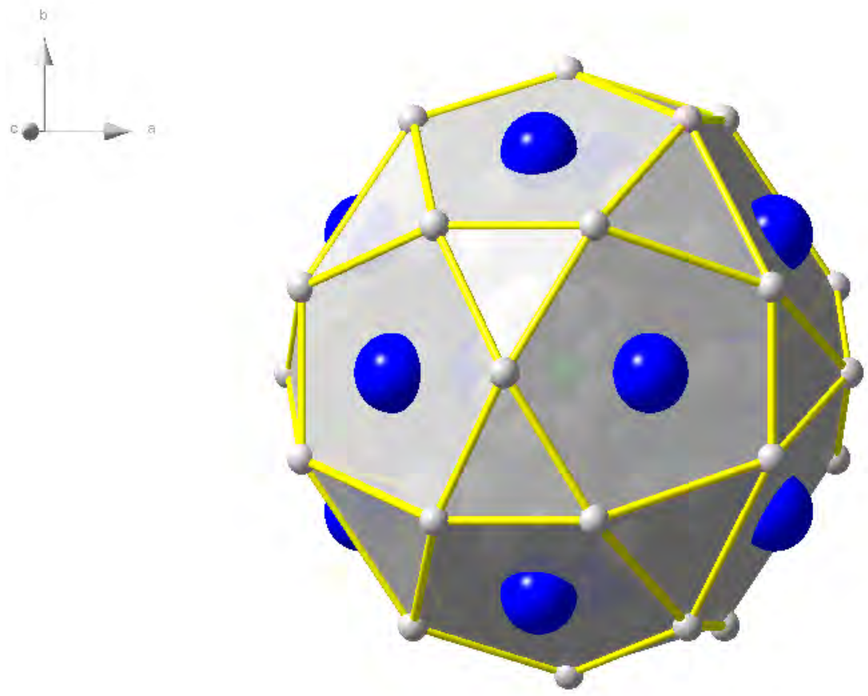


Icosaèdre

R=5.6 Å

Ordre chimique

Amas atomique

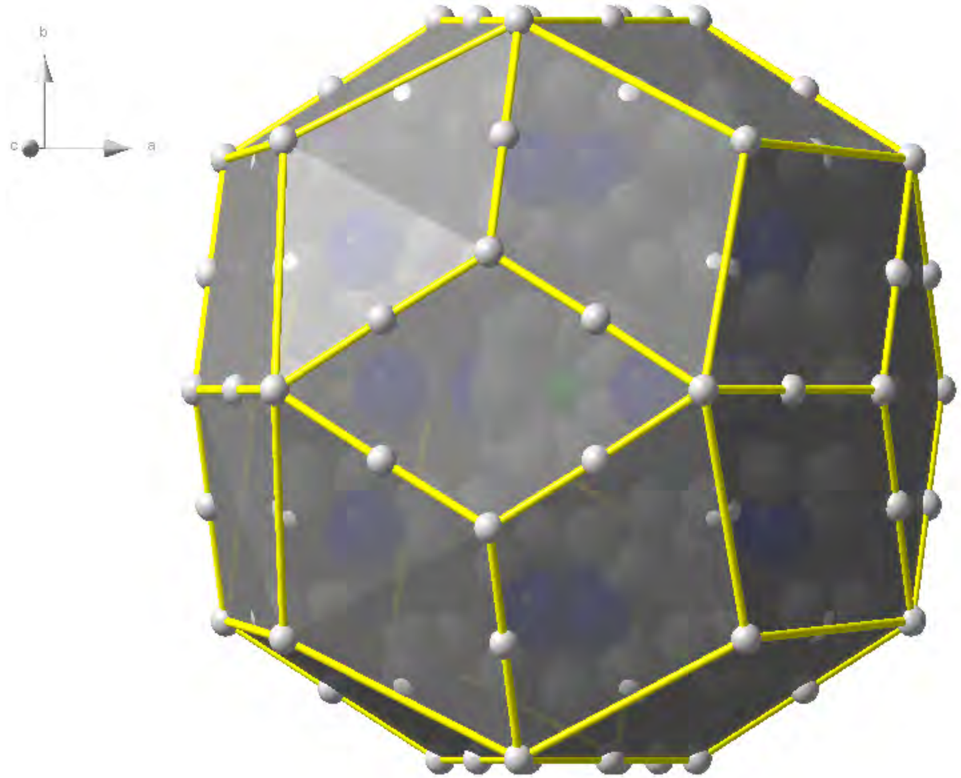


Cd icosi-dodecaèdre

R=6.5 Å

ORDRE CHIMIQUE

Amas atomique



Cd Triacontraèdre

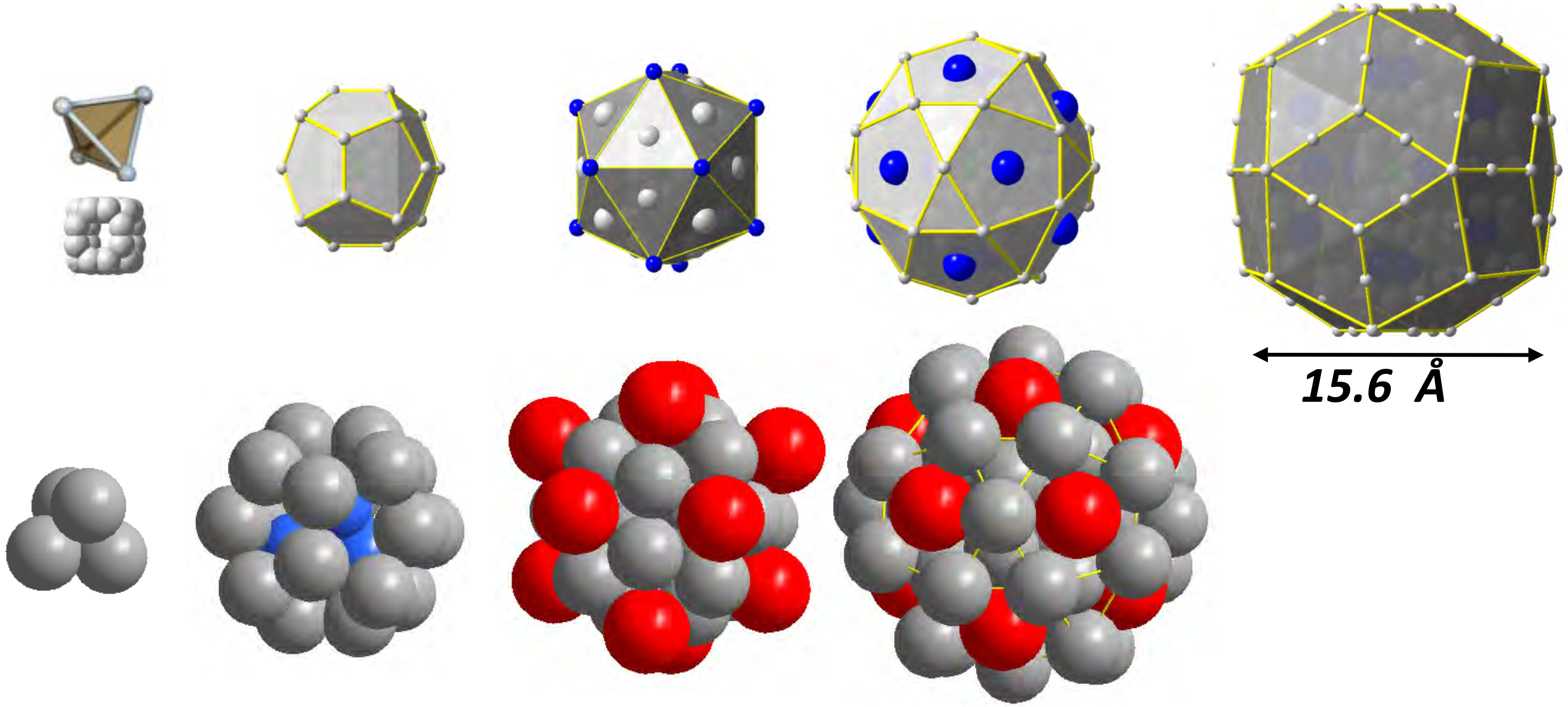
R=7.8 Å

Total de 158 atomes

Closed packed structure, small (Cd) and large (Yb) atom.

*Gomez C P and Lidin S 2003 Phys. Rev. B **68** 024203\1.*

Amas atomique

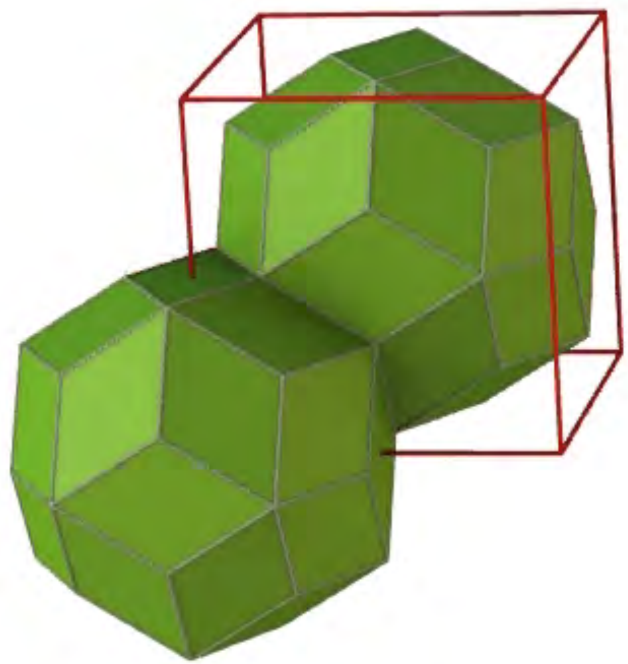


158 atomes. ***Ordre Chimique***

Empilement compact de deux atomes.

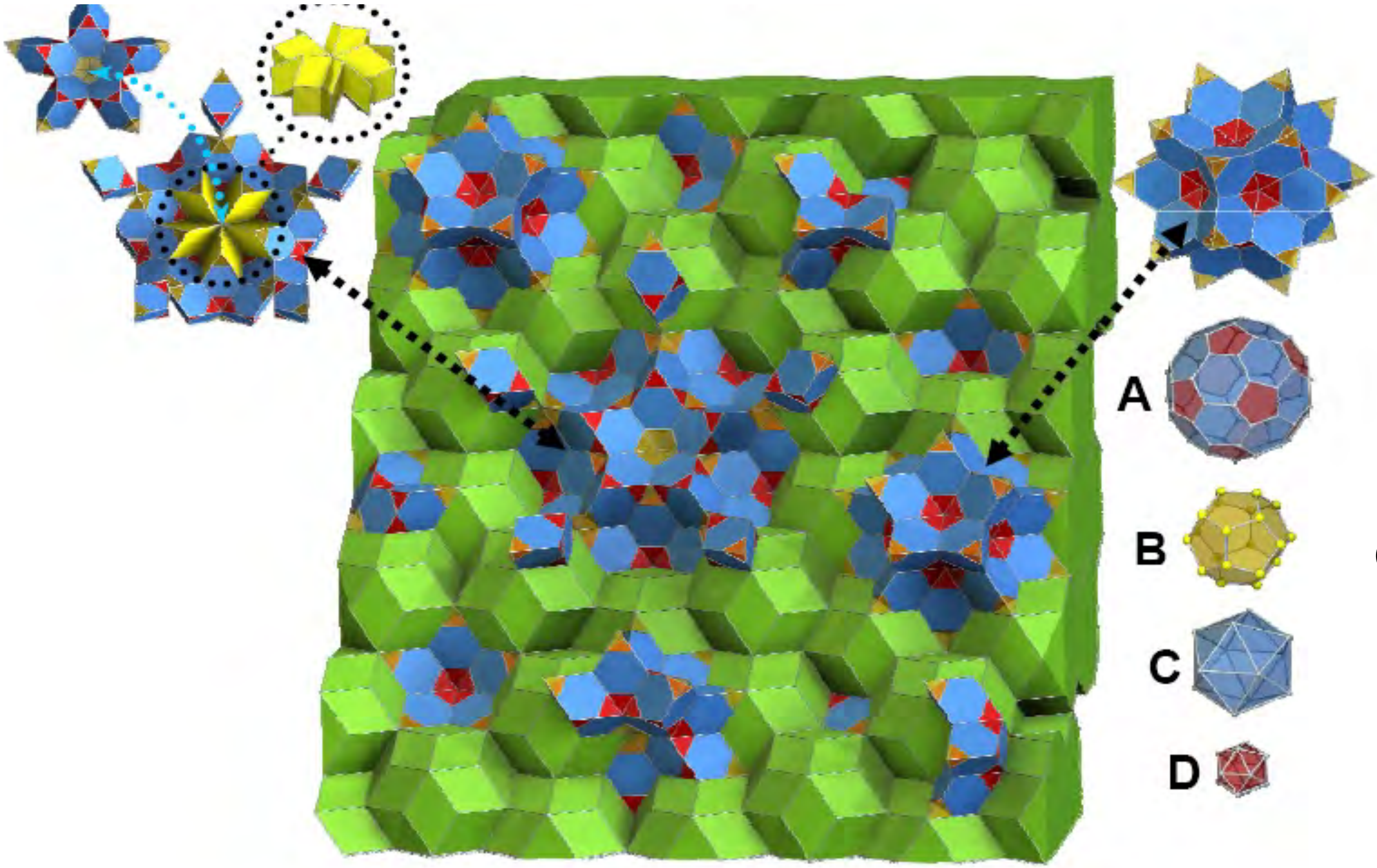
Connection des amas: le long des axes 3

Approximant périodique: Paramètre de maille 1.5nm



Même connection dans le quasicristal

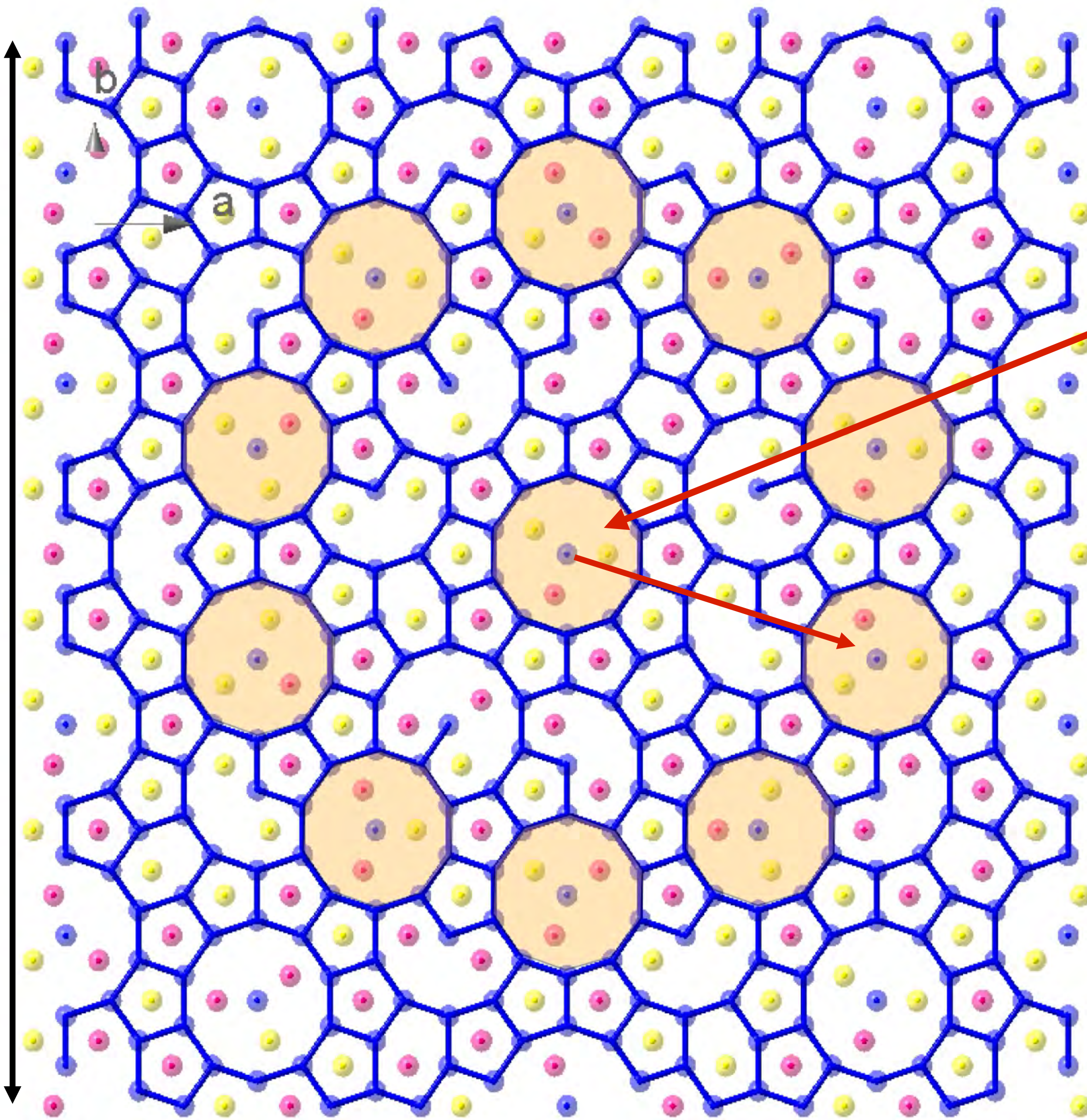
Quasicristal i-CdYb amas atomique



Bergman Cluster

H. Takakura, C. Gomez, A. Yamamoto et al., Nature Materials, , 2007,6,58

Empilement hierarchique des amas



~ 340 Å

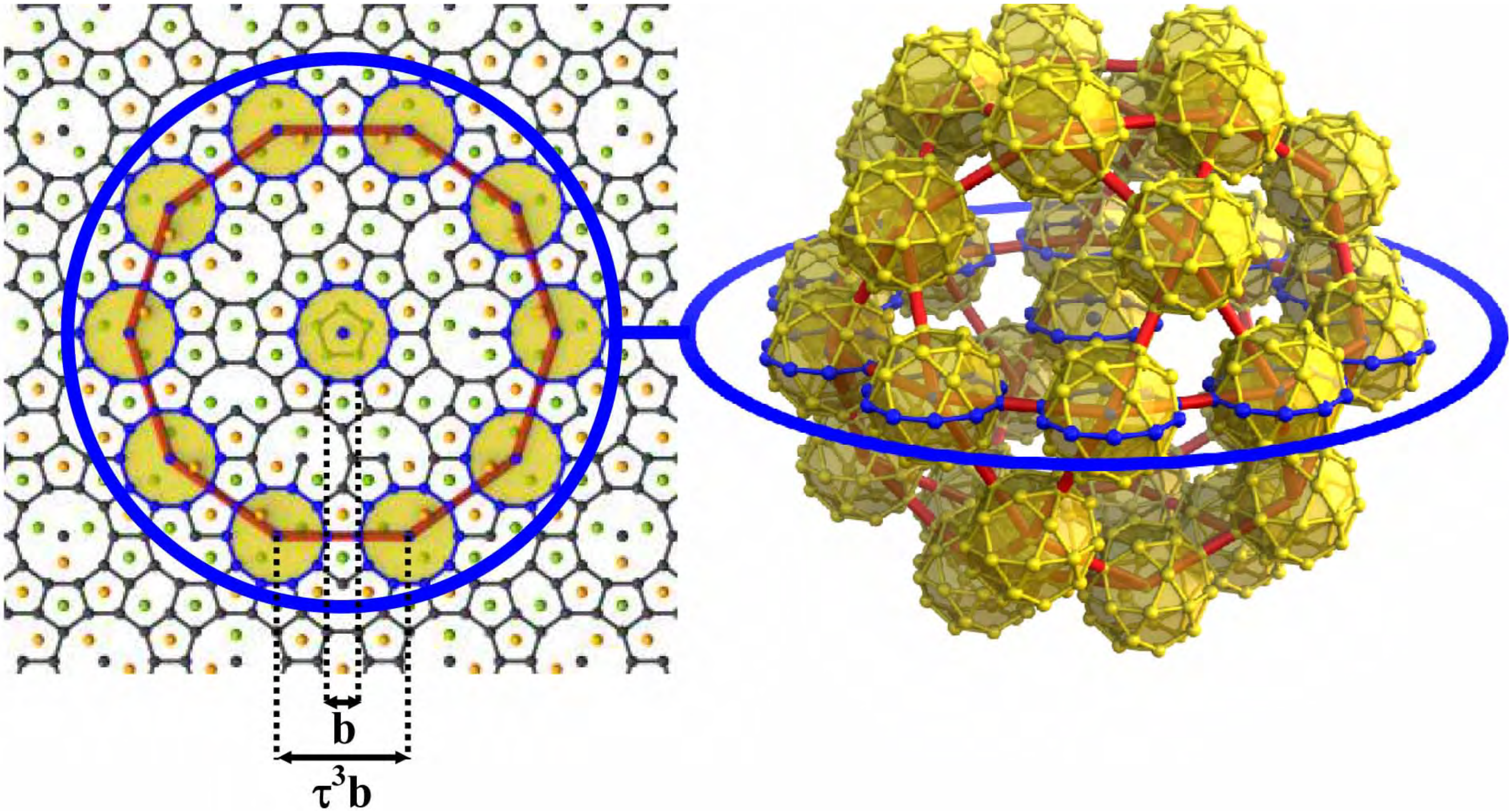
Plan d'axes 5

Amas d'amas (R_1=25 Å)

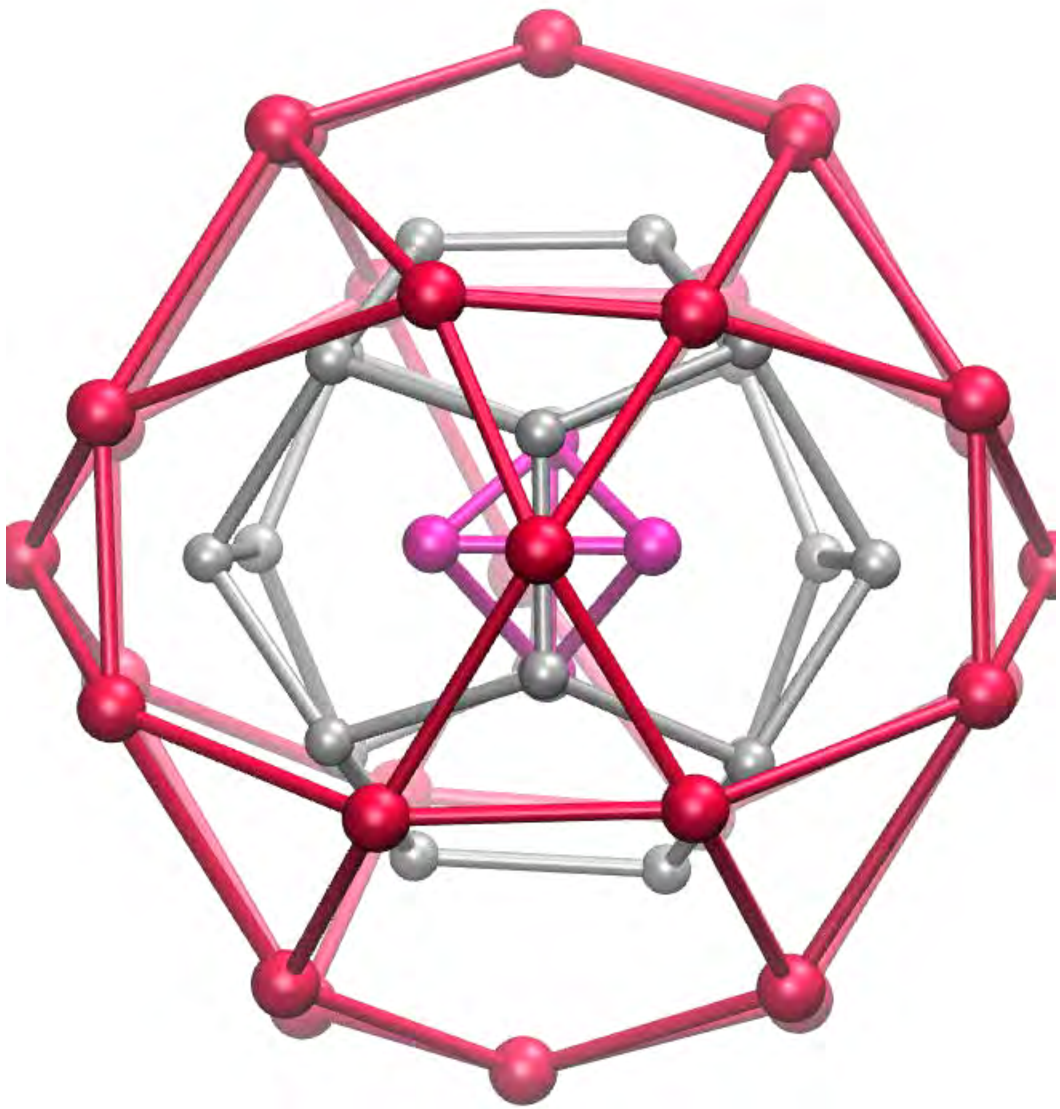
Amas, d'amas, d'amas (R= $\tau^3 R_1$=107 Å)

Quasicristal: Empilement d'amas

Position des centres des amas

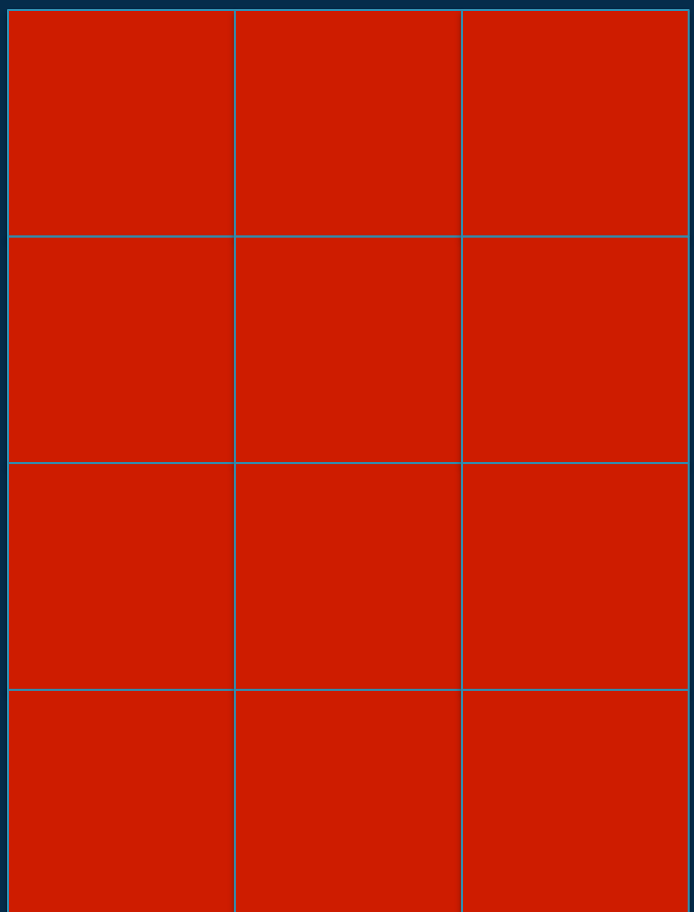


Dans le quasicristal CdYb le tétraèdre central se réoriente:
Saut tous les 1ps (10^{-12} seconde)

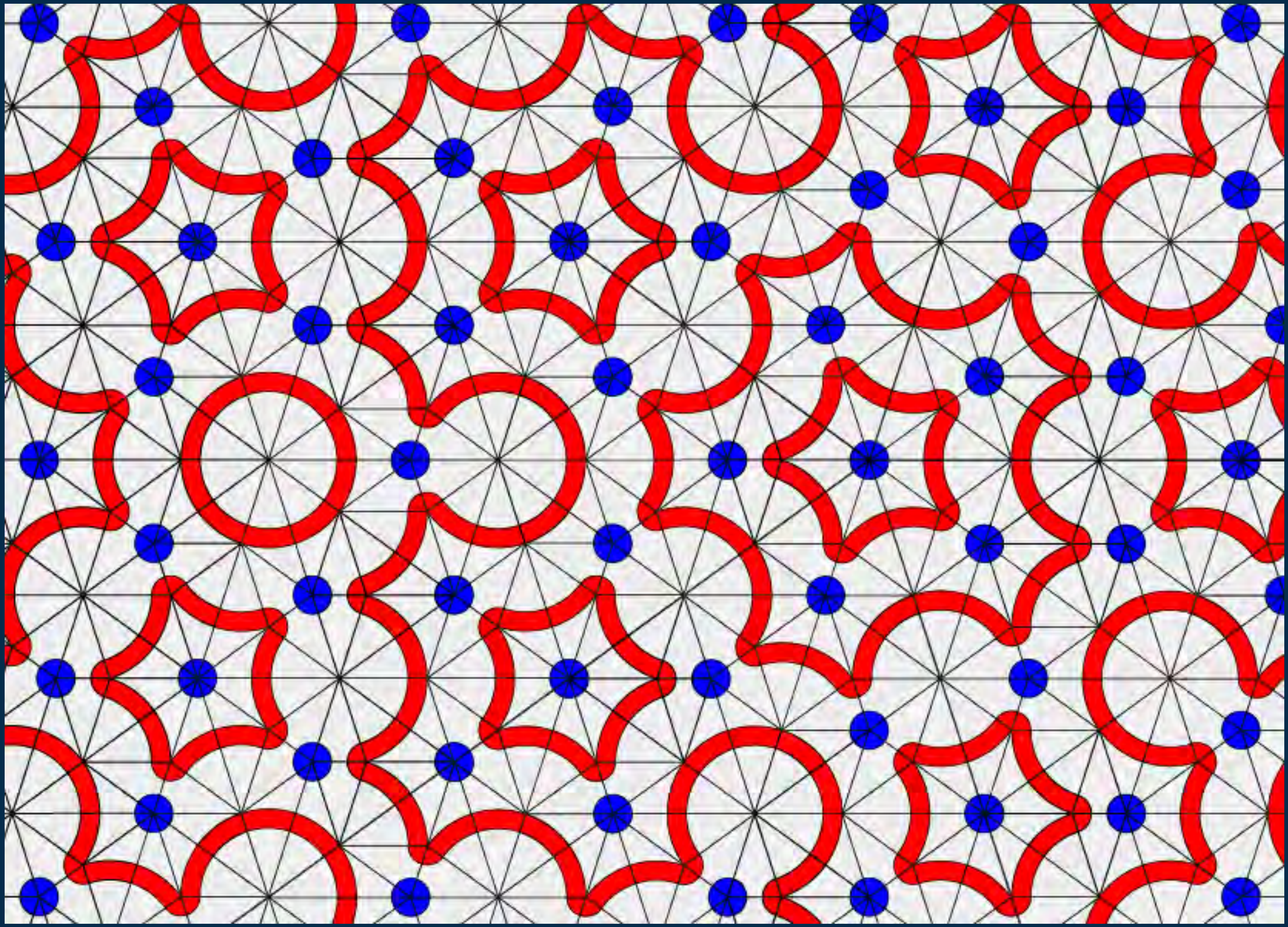


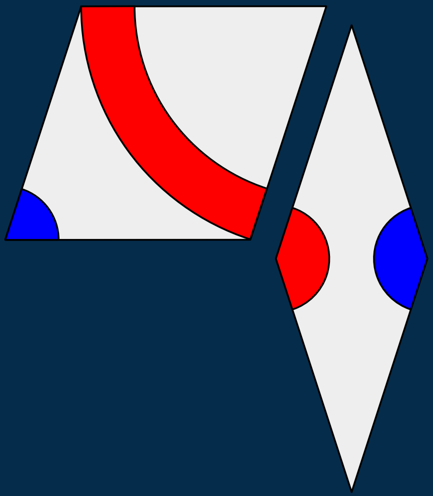
Cristal : Symétrie et périodicité

La symétrie 4 est compatible avec la périodicité



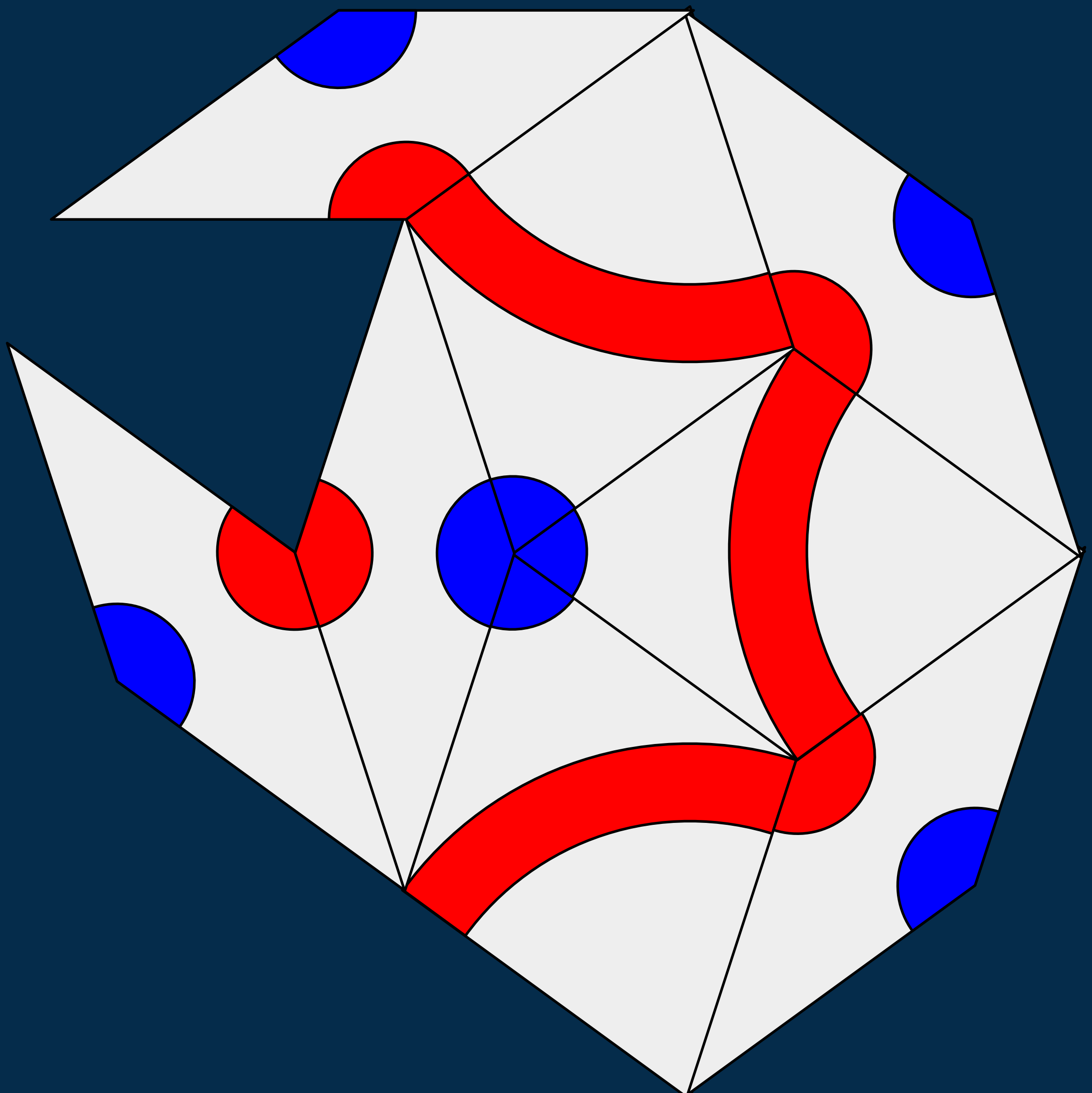
Comment faire ‘pousser’ un quasicristal?



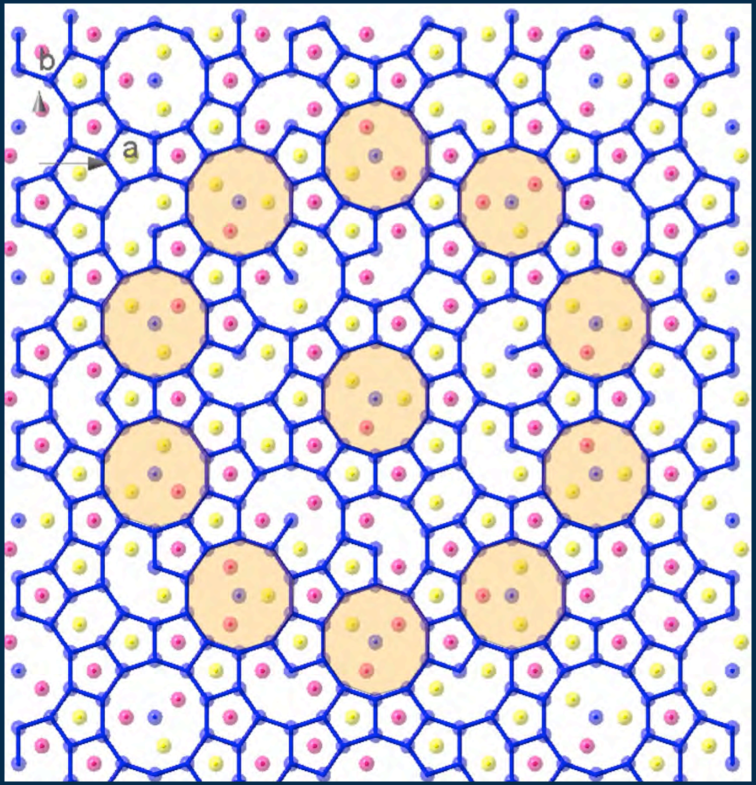


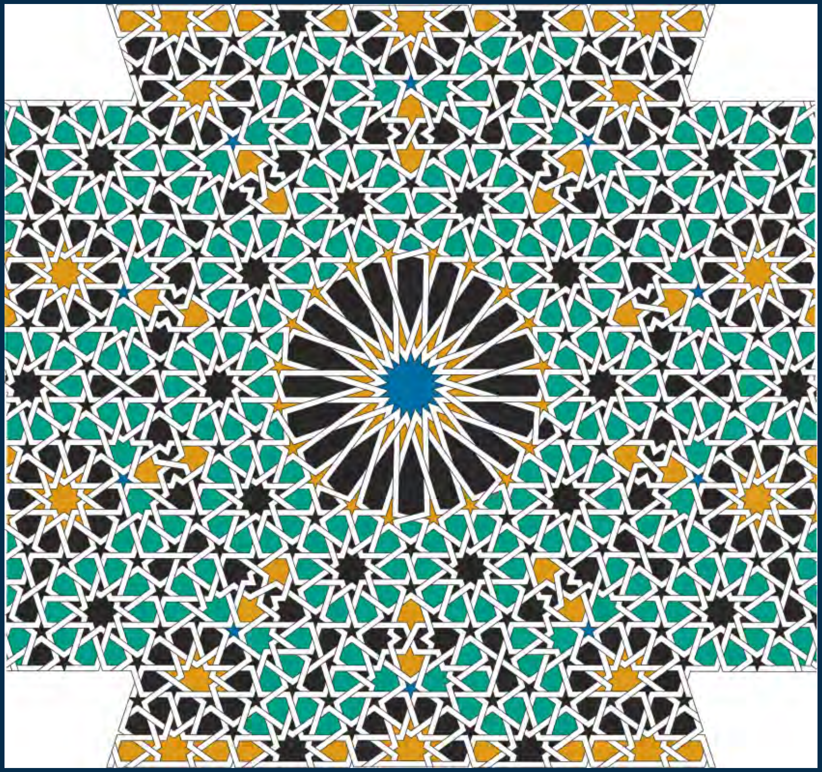
Rêgles d’assemblage

Croissance: un problème complexe



Les quasicristaux
Une étrange mosaique d'atomes





Mosaique, Alhambra Espagne