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Aperiodic Crystals

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Until the 1970s, all materials studied consisted of periodic arrays of unit cells, or were amorphous. In the last decades a new class of solid state matter, called aperiodic crystals, has been found. It is a long range ordered structure, but without lattice periodicity. It is found in a wide range of materials: organic and anorganic compounds, minerals (including a substantial portion of the earths crust), and metallic alloys, under various pressures and temperatures. Because of the lack of periodicity, the usual techniques for the study of structure and physical properties no longer work, and new techniques have to be developed. This book deals with the characterization of the structure, the structure determination, and the study of the physical properties, especially dynamical and electronic properties of aperiodic crystals. The treatment is based on a description in a space with more dimensions than three, the so-called superspace. This allows us to generalise the standard crystallography and to look differently at the dynamics. The three main classes of aperiodic crystals, modulated phases, incommensurate composites, and quasicrystals are treated from a unified point of view, which stresses the similarities of the various systems.

SYSTEMATIC CRYSTAL CHEMISTRY

Sander Van Smaalen

in Incommensurate Crystallography

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This chapter gives an overview of compounds with incommensurate crystal structures. Superspace is an excellent tool for crystal chemical considerations, as it is demonstrated for selected classes of compounds

with incommensurate crystal structures as well as for compounds with periodic structures. The relations between individual compounds of a homologous series can be better understood by employing a unified superspace group and a unified structure model for all compounds in such a series. Relations between commensurately and incommensurately modulated structures of the different phases of A2BX4 type compounds are made explicit by the superspace approach. So-called t-plots are introduced as a versatile method for the crystal chemical analysis of incommensurately modulated structures and composite crystals. They are used to analyse the stability of the incommensurate structures of the chemical elements, and to compute the atomic valences in aperiodic crystals.

SYMMETRY OF MODULATED CRYSTALS

Sander Van Smaalen

in Incommensurate Crystallography

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This chapter gives a comprehensive account of the symmetry of incommensurately modulated crystals. Diffraction symmetry is shown to be given by a crystallographic point group as it is known from the crystallography of periodic crystals. A complete list of symmetry restrictions on modulation wave vectors is derived from this property. The symmetry of incommensurate crystals with an one-dimensional modulation is given by (3+1)-dimensional superspace groups. The latter are defined as a subset of the space groups in four-dimensional space. A thorough discussion is given of the notation of superspace groups, of equivalence relations between them, and of their various settings. Symmetry properties of modulation functions and other structural parameters are presented. An expression is derived for the structure factor of Bragg reflections that incorporates the full superspace symmetry of the incommensurately modulated structure.

INCOMMENSURATE COMPOSITE CRYSTALS

Sander Van Smaalen

in Incommensurate Crystallography

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This chapter introduces the superspace description of the crystal structures of incommensurate composite crystals, and the characterization of their symmetry by superspace groups. The treatment parallels that of incommensurately modulated crystals in most aspects. The particular features of composite crystals are highlighted with respect to the diffraction and structure in superspace, superspace groups, the structure factor of Bragg reflections, and t-plots.

SUPERSTRUCTURES AND THE COMMENSURATE APPROXIMATION

Sander Van Smaalen

in Incommensurate Crystallography

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This chapter develops the relation between crystal structures of aperiodic crystals and superstructures. Superstructures are described as commensurately modulated structures, and it is shown that superspace methods can be applied to this particular kind of periodic crystals. Alternatively, superstructures are obtained as the commensurate approximation to incommensurately modulated crystals and composite crystals. Relations are derived between modulation functions and superspace groups of the modulated-structure description, and atomic coordinates and supercell space groups of the superstructure description.

SUSY LAGRANGIANS

John Terning

in Modern Supersymmetry: Dynamics and Duality

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This chapter discusses the development of SUSY Lagrangians. Topics covered include the free Wess-Zumino model, commutators of SUSY transformations, an extension of the auxiliary field formalism to the gauge interactions of massless vector multiplets, SUSY gauge theories, and superspace. Exercises are provided at the end of the chapter.

Supersymmetry

Gian Francesco Giudice

in A Zeptospace Odyssey: A Journey into the Physics of the LHC

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Superspace is an extension of space-time which includes new coordinates with unusual algebraic rules. The nature of superspace is quantum mechanical, because it requires the concept of particle spin. This chapter describes the meaning of superspace and supersymmetry, and shows how these ideas can provide a solution to the naturalness problem. The impact of supersymmetry in the quest for unification is also discussed, from its role in superstring theory to the result of gauge coupling unification. Finally, the chapter describes how experiments at the LHC could discover supersymmetry.

Hamiltonian formulation of general relativity

Claus Kiefer

in Quantum Gravity: Third Edition

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This chapter, although dealing entirely with classical physics, prepares the ground for the following chapters by developing in full detail the Hamiltonian, or canonical, formulation of general relativity, also called 3+1 decomposition. This is achieved by a decomposition of four-dimenensional spacetime into a foliation of spacelike hypersurfaces. Special attention is devoted to open spaces and the structure of the configuration space. The canonical formalism is presented for metric, connection, and loop variables.

Beyond the Standard Model

Laurent Baulieu, John Iliopoulos, and Roland Sénéor

in From Classical to Quantum Fields

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The motivation for supersymmetry. The algebra, the superspace, and the representations. Field theory models and the non-renormalisation theorems. Spontaneous and explicit breaking of super-symmetry.
The generalisation of the Montonen–Olive duality conjecture in supersymmetric theories. The remarkable properties of extended supersymmetric theories. A brief discussion of twisted supersymmetry in connection with topological field theories. Attempts to build a supersymmetric extention of the standard model and its experimental consequences. The property of gauge supersymmetry to include general relativity and the supergravity models.