# Workshop on Quantum Field Theory aspects of Condensed Matter Physics

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# *Abstract book*

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**Graphene vs. carbon nanotubes, a comparative characterization**

**S. BELLUCCI (LNF INFN)**

**Rigorous construction of Luttinger liquids through Ward Identities**

**Giuseppe BENFATTO (Tor Vergata Univ.)**

There are many fermion models (one-dimensional Fermi gas at low temperature, Hubbard model, XYZ model, a large class of classical two-dimensional spin systems), whose rigorous infrared RG analysis is based on two key properties:

1) The flow of the effective coupling (the beta function) is the same, up to exponentially small terms, as the analogous flow for the spinless Tomonaga model, that is the Luttinger model with ultraviolet cutoff and local interaction, which is equivalent to the Thirring model with fixed ultraviolet cutoff. I shall briefly discuss the technical ingredients, which allow to prove this property.

2) The beta function for this special model (which is not solvable) is asymptotically vanishing, so that the effective coupling on large scales is essentially constant and of the same order of the coupling on small scales. The most clear proof of this property is based on the Ward identities obtained by a chiral local gauge transformation, applied to the Tomonaga model with infrared cutoff (which is removed at the end). This is an old approach in the physical literature, but its implementation in an RG scheme is not trivial at all, because the ultraviolet and infrared cutoffs destroy local Gauge invariance and produce ``correction terms'' with respect to the formal Ward identities. I shall discuss how to control these terms.

**Infrared phonon activity and quantum Fano interference in multilayer graphemes**

**Emmanuele CAPPELLUTI (ICMM, CSIC, Madrid, Spain)**

**Lara Benfatto (ISC, CNR, Rome Italy)**
**Alexey Kuzmenko (DPMC, Geneve Univ.)**

The detection and analysis of the spectral properties of optical phonon in single-layer and multilayer graphene provides a powerful tool not only for a careful characterization of the systems but also for investigating the role of the underlying electron-phonon interaction.

Recent experiments in gated bilayer graphene revealed a clear phonon resonance at 1590 cm-1 with several interesting features, as for instance a giant enhancement of the phonon intensity as a function of the gate voltage as well as a pronounced Fano lineshape asymmetry.

In this contribution we show how these features can be analyzed and predicted on a microscopic quantitative level using a charge-phonon theory applied to the specific case of graphene systems.

We show in particular how the phonon intensity and the Fano asymmetry are strictly related, stemming out from the quantum interference between the electronic and phononic degrees of freedom.

Within this context we are also able to elucidate the relative role of the Eu and Eg phonon modes in regards to the infrared activity and the Fano asymmetry of the observed phonon peaks.

We present thus a complete phase diagram for the strength of the phonon modes and their Fano properties as functions of the chemical potential and of the gated-induced electronic gap, showing that a switching mechanism between the dominance of the Eu or Eg mode can be controlled by the external gate voltage.

Our work permits thus reconciling within a unique theoretical approach the phonon-peak features observed by different experimental groups, and it provides an analytical tool for predicting and controlling on a quantitative level the spectral properties of the phonon resonances in the infrared spectra of graphenes.

**Superconductivity and Pseudogap Phase close to the Mott transition**

**Claudio CASTELLANI (Roma Univ.)**

We have recently proposed a Strongly Correlated Superconductivity (SCS) scenario related to the question whether and under which conditions Cooper pairing may be fa strong electron repulsion close to a Mott transition. The key of the SCS proposal effective repulsion between quasiparticles vanishes close to the Mott transition, while attraction which involves spin degrees of freedom remains unrenormalized. Ur conditions, the superconducting order parameter may be greatly enhanced by approa Mott transition. This scenario, originally demonstrated through a Dynamical M Theory (DMFT) solution of a three-band Hubbard model for doped fullerenes, recently extended to a twofold orbitally degenerate model with on site exchange ir Solving the model as a function of density, we obtain an extremely appealing phase where superconductivity arises by doping the Mott insulator, out of a pseudogapped phase, very much as it happens in cuprates. The appearance of the pseudogap is re 'local' critical point of the Anderson impurity model that DMFT associates to th lattice model. From this point of view our model has strong similarities with the Critical Point scenarios, with the advantage of a non perturbative solution.

References:

Massimo Capone, Michele Fabrizio,Claudio Castellani, and Erio Tosatti, Correlated Superconductivity", Science 296, 2364 (2002); "Strongly ( Superconductivity and Pseudogap Phase near a multi-band Mott insulator", Phys 93, 047001 (2004); "Modeling the Unconventional Superconducting Prop Expanded $A_3C_{60}$ Fullerides", Rev.Mod.Phys. 81, 943 (2009).

**Aharonov-Bohm interferences from local deformations in graphene**

**Fernando de JUAN (Indiana Univ.)**

Since the early observation of ripples in the graphene samples, the membrane-like properties of graphene have given rise to a very active investigation that remains open up to today. The interplay of structural and electronic properties is successfully described by the modeling of curvature and elastic deformations by fictitious gauge fields, whose experimental reality has been recently observed: the Landau levels induced when these fields are strong have been identified in tunneling experiments. In this work we show that an Aharonov-Bohm effect can be observed linked to the fictitious magnetic fields induced by mechanical deformations
of the graphene samples. On this basis, we propose a scanning-tunneling-microscopy device to detect stresses via Aharonov--Bohm interfences in the weak field limit.

## RG flows and phase diagrams from lattice simulations

**L. DEL DEBBIO (Edinburgh Univ.)**

We discuss some results on the RG flows in QFT obtained by numerical simulations of the theory regulated on a spacetime lattice.

**From Classical to Quantum Critical Phenomena**
**in Condensed Matter Physics: a specific case, the Cuprates**

**C. DI CASTRO (Roma Univ.)**

Within the framework of RG approach, the d=1 interacting electron system is recalled. Infrared divergences are present well inside the liquid stable phase. Additional symmetries and related Ward Identities implement cancellation of singularities to all orders in the response functions and allow for the asymptotic solution of the problem. A non Fermi liquid (Luttinger liquid) is obtained. However a normal FL is recovered as soon as d>1, except in the presence of singular effective interaction, e. g. nearby an instability. This seems to be the case of Cupates.
As glue mediators in Cuprates, Raman spectroscopy identifies two modes, spin and charge with different characteristic wave vectors. The relative importance of the two scattering mechanisms switches from spin to charge by increasing doping. Simultaneous presence of spin and charge-density fluctuations suggests both charge and spin ordering as competing phase.
This is a confirmation of Quantum Criticality leading to inhomogeneous states formation with various morphologies (stripes, droplets,…) arising as Fermi Liquid instability of charge modulation at high doping (Rome proposal) evolving into spin dominated structures when the AFM region is approached at low doping (Emery and Kivelson proposal).
At low doping glass of nematic V-A chain segments give rise to smectic correlations like in stripe phase (at least in the spin sector) and are the seeds for more compact structures (checkerboard, bubbles…).

**The KZ Anomaly in Topological Insulators: An Introduction**

**Miguel Angel Martin DELGADO (Madrid Univ.)**

An introduction is given to the notion of Topological Insulators by reviewing the notion of quantum insulating states. A simple example is provided by the Creutz ladder in condensed matter and high-energy physics. Then, we study the influence of topology on the quench dynamics of a system driven across a quantum critical point. We show how the appearance of certain edge states, which fully characterize the topology of the system, dramatically modifies the process of defect production during the crossing of the critical point. Interestingly enough, the density of defects is no longer described by the Kibble-Zurek scaling, but determined instead by the non-universal topological features of the system. Edge states are shown to be robust against defect production, which highlights their topological nature. The KZ anomaly provides a dynamical characterization of Topological Insulators.

# 3D Topological States of Matter and the Vortex Quantum Hall Effect

**Cristina DIAMANTINI (Perugia Univ.)**

Topological matter is characterized by the presence of a topological BF term in its long-distance effective action. Topological defects due to the compactness of the U(1) gauge fields induce quantum phase transitions between topological insulators, topological superconductors and topological confinement. In conventional superconductivity, due to spontaneous symmetry breaking, the photon acquires a mass due to the Anderson-Higgs mechanism. In this paper we derive the corresponding effective actions for the electromagnetic field in topological superconductors and topological confinement phases. In topological superconductors magnetic flux is confined and the photon acquires a topological mass through the BF mechanism: no symmetry breaking is involved, the ground state has topological order and the transition is induced by quantum fluctuations. In topological confinement, instead, electric charge is linearly confined and the photon becomes a massive antisymmetric tensor via the St\"uckelberg mechanism. Oblique confinement phases arise when the string condensate carries both magnetic and electric flux (dyonic strings). Such phases are characterized by a vortex quantum Hall effect.

# Bilayer graphene: band topology, interaction-driven nematic phase transition, and strain effects

**Vladimir FALKO**

# Electron-electron interactions in graphene

**Francisco GUINEA (CSIC)**

Electronic interactions in graphene induce interesting changes in the band structure, not found in other materials. Recent experiments, and theoretical work, will be reviewed which suggest that single layer graphene behaves as a "marginal Fermi liquid". The effect of interactions is enhanced in disordered samples, possibly leading to the existence of local magnetic moments and novel magnetic properties.

**Geometric field theory ("quantum geometry") description of the fractional quantum Hall effect**

**M.D.M. HALDANE (Princeton Univ.)**

I will describe recent work on the FQHE which reveals that its fundamental description involves the "quantum geometry" of a "guiding center metric" which is a local unimodular metric field determining the shape of the "elementary droplet" of FQHE fluid. (This geometrical field is absent in the integer QHE.) The long-wavelength L=2 FQHE collective mode is identified as a "graviton-like" fluctuation of this metric field, and the obscure "shift" parameter of the FQHE is related to a fundamental "guiding center spin" that is central to the description of incompressibility: deviations of the charge density relative to that determined by the Hall relation and flux density are given by this spin times the Gaussian curvature of the metric field.
The new picture leads to a new "Chern-Simons+geometry" description of FQHE incompressibility.

**Order parameters and their topological defects in 2D Dirac systems**

**I. HERBUT (Simon Fraser Univ.)**

The system of spin-1/2 electrons hopping on the two-dimensional honeycomb or on the pi-flux square lattice allows for 36 linearly independent order parameters that gap the Dirac points at the filling one half.
These can be grouped into the four types of insulators, each coming in the spin-singlet and spin-triplet versions, and the four types of superconductors, out of which three are spin-triplets and only one is a spin-singlet. I will discuss some algebraic properties satisfied by these order parameters, universally obeyed in the Dirac systems in two dimensions, together with their physical consequences. In particular, the core of a vortex configuration in any two mutually anticommuting mass-order-parameters will be shown to be unavoidably occupied by some of the remaining 34 order parameters.

**Rings, boxes and spins with dissipative environments**

**Baruch HOROVITZ (Ben Gurion Univ. - Israel)**

We study a particle on a ring in presence of a dissipative Caldeira-Leggett environment and derive its nonequilibrium response to a DC ¯eld [1]. We ¯nd, through a 2-loop renormalization group analysis, that a large dissipation parameter ´ °ows to a ¯xed point ´c = ~=21/4. We also reexamine the mapping of this problem to that of the Coulomb box and show that the relaxation resistance, of recent interest, has a certain average that is quantized for ´ > ´c leading to quantized noise.
When the particle carries a spin with spin-orbit interactions [2] we ¯nd that the spin correlations in the direction perpendicular to the ring are ¯nite at long times, i.e. do not dephase, while the parallel components seem to decay as a power law at strong dissipation.

[1] Y. Etzioni, B. Horovitz and P. Le Doussal, Phys. Rev. Lett. 106, 166803 (2011)
[2] B. Horovitz, P. Le Doussal and G. Zarand, arXiv:1104.1637

## The Hawking-Unruh effect on graphene

**A. IORIO (Charles Univ.)**

If indeed the massless 2+1d Dirac pseudoelectrons, arising in the low energy limit theory governing the electronic properties of graphene, experience a general-relativistic (curved spacetime) environment, then Weyl-gauge symmetry would play a crucial role. This symmetry, enjoyed in its local form by the system, provides a powerful tool to connect a vast class of spacetimes to the flat one, the latter being the ideal candidate for the lab frame. Along with the specific properties of gravity theories in 2+1d, this suggests a general method to test in the lab whether the exotic scenarios of QFT in curved spacetimes, such as the Hawking/Unruh phenomenon, could indeed take place on graphene.
In this talk, I shall introduce the general results obtained last year (by also reviewing the basic facts on Weyl symmetry) and shall then focus on recent and on-going work where a proposal for an experimental test is under construction. An important part of the latter effort is the identification of a technical-problems-free and measurements-friendly specific set-up, the proposed answer being what I call the ``Beltrami spacetime'', an AdS_3 spacetime conformal to a Rindler spacetime.

**Representation for planar zero-mode operators, both even and odd**

**R. JACKIW (MIT)**

Superconductors in contact with topological insulators can be described by a planar Majorana - type equation, which supports isolated zero-energy modes in the presence of vortices. The algebra of the associated operators is described

**Quantum phase transitions in the 3d Thirring model**

**L. JANSSEN (Friedrich Schiller University Jena)**

"3d relativistic fermion system have fascinating applications to condensed-matter systems: In particular, QED3 and the 3d Thirring model are actively discussed, e.g., as effective theories describing different regions of the cuprate phase diagram and the electronic properties of graphene. Nonetheless, these theories are likewise intrinsically interesting: most notably, it is expected that chiral symmetry breaking is prohibited once the number of fermion flavors is larger than a critical value. In this talk I review the 3d Thirring model and its symmetries. With the help of the functional renormalization group I discuss the UV structure and possible condensation channels. I then reformulate the model in a partially bosonized language which is suitable for the investigation of dynamical mass generation."

# Spin and charge dynamics in a 1D correlated electron system with modulate spin-orbit interaction

**George JAPARIDZE (Andronikashvili Inst. Physics)**

We study the effect of spatially modulated Rashba spin-orbit interaction on the low-energy dynamics of a one-dimensional correlated electrons with uniform, Rashba plus Dresselhaus, spin-orbit coupling. For different values of the wave number of the modulation, commensurate with different diameters of the, characterized by four Fermi point Fermi surface of the system, we shown that a spatially modulated Rashba spin-orbit coupling drives a transitions a) from a Luttinger-liquid (LL) to an band-insulating (BI) state and b) from a metallic to a quasi-Helical liquid (QHL) state. Using an effective field theory approach, we also carry out an analysis of effects from electron-electron interactions. In the case of LL-BI transition we show how the single-particle gap in the insulating state can be extracted from the more easily accessible collective charge and spin excitation thresholds and also give estimation for enhancement of the gap caused by e-e interaction.

**Magnetic pairing**

**Gianni JONA-LASINIO (INFN Roma 1)**

The Dirac field in 2+1 dimension in presence of a constant magnetic field is an exactly solvable problem. If analysed in terms of the degrees of freedom of the free field a pairing structure emerges for any value of the mass, as shown long ago in a paper with Francesca Marchetti. This provides an explanation for chiral symmetry breaking in NJL models in presence of a magnetic field and very weak nonlinearity. Such a phenomenon, studied by Gusynin, Miransky and Shovkovy and called magnetic catalysis, has acquired a novel interest in connection with the physics of graphene.

**Graphene: CERN on the desk**

**Mikhail KATSNELSON (Radboud University Nijmegen)**

Graphene, a recently (2004) discovered two-dimensional allotrope of carbon (this discovery was awarded by Nobel Prize in physics 2010), has initiated a huge activity in physics, chemistry and materials science, mainly, for three reasons. First, a peculiar character of charge carriers in this material makes it a "CERN on the desk" allowing us to simulate subtle and hardly achievable effects of high energy physics. Second, it is the simplest possible membrane, an ideal testbed for statistical physics in two dimensions. Last not least, being the first truly two-dimensional material (just one atom thick) it promises brilliant perspectives for the next generation of electronics which uses mainly only surface of materials. I will tell about the first aspect of the graphene physics, some unexpected relations between materials science and quantum field theory and high-energy physics.

Electrons and holes in this material have properties similar to ultrarelativistic particles (two-dimensional analog of massless Dirac fermions). This leads to some unusual and even counterintuitive phenomena, such as finite conductivity in the limit of zero charge carrier concentration (quantum transport by evanescent waves) or transmission of electrons through high and broad potential barriers with a high probability (Klein tunneling). This allows us to study subtle effects of relativistic quantum mechanics and quantum field theory in condensed-matter experiments, without accelerators and colliders. Some of these effects were considered as practically unreachable. Apart from the Klein tunneling, this is, for example, a vacuum reconstruction near supercritical charges predicted many years ago for collisions of ultra-heavy ions. Another interesting class of quantum-relativistic phenomena is related with corrugations of graphene, which are unavoidable for any two-dimensional systems at finite temperature. As a result, one has not just massless Dirac fermions but massless Dirac fermions in curved space. Gauge fields, of the central concepts of modern physics, are quite real in graphene and one can manipulate them just applying mechanical stress.

**Anderson localization in quark-gluon plasma**

**Tamas KOVACS (Pecs Univ. - Department of Physics)**

In the high temperature phase of Quantum Chromodynamics the lowest quark states of the Dirac operator are localized and the corresponding eigenvalues are statistically uncorrelated. Higher up in the spectrum eigenvectors become delocalized and the corresponding spectral statistics is described by Random Matrix Theory. This remarkable phenomenon, analogous to Anderson localization, appears to be a general property of non-Abelian gauge theories in four space-time dimensions. We demonstrate this phenomenon using numerical simulations and also speculate on its possible physical origin.

**Magnetic monopoles in (2+1)-d Compact QED**

**Biagio LUCINI (Swansea Univ.)**

We present the first evidence from lattice simulations that the magnetic monopoles in three dimensional compact quantum electrodynamics (cQED3) with N_f=2 and N_f= 4 four-component fermion flavors are in a plasma phase. The evidence is based mainly on the divergence of the monopole susceptibility (polarizability) with the lattice size at weak gauge couplings. A weak four-Fermi term added to the cQED3 action enabled simulations with massless fermions. The exact chiral symmetry of the interaction terms forbids symmetry breaking lattice discretization counterterms to appear in the theory's effective action. It is also shown that the scenario of a monopole plasma does not depend on the strength of the four-Fermi coupling. Other observables such as the densities of "isolated" dipoles and monopoles and the so-called specific heat show that a crossover from a dense monopole plasma to a dilute monopole gas occurs at strong couplings. The implications of our results on the stability of U(1) spin liquids in two spatial dimensions.

**Anomalous charge tunneling in the fractional quantum Hall edge states at filling factor \nu = 5/2**

**N. MAGNOLI**

We explain effective charge anomalies recently observed for fractional quantum Hall edge states at \nu=5/2 [1, 2]. The experimental data of differential conductance and excess noise are fitted, using the anti-Pfaffian model, by properly take into account renormalizations of the Luttinger parameters induced by the coupling of the system with an intrinsic 1/f noise. We demonstrate that a peculiar agglomerate excitation with charge e/2, double of the expected e/4 charge, dominates the transport properties at low temperatures and bias.

[1] M. Dolev, Y. Gross, Y. C. Chung, M. Heiblum, V. Umansky, and D. Mahalu, Phys. Rev. B. 81, 161303(R) (2010)

## Magnetic and Electronic Spectrum of Iron-Pnictides

**Eduardo MARINO (UFRJ)**

We calculate the magnetic and electronic quasiparticle excitation spectra for iron-pnictide superconductors, using a J(1)-J(2) model with itinerant electrons. The magnetic spectrum presents two branches: an optical branch, which is gapped and an accoustic branch, which also becomes gapped by virtue of local anisotropies. The electronic quasiparticle spectrum is composed of two Dirac cones, resulting from the folding of the magnetic Brillouin zone within the magnetically ordered phase. We compare our findings with experimental results coming from neutron scattering and photoemission ,experiments done with SrFe(2)As(2).

Ref.: C.M.S. da Conceicao, M.B. Silva Neto, E.C.Marino, Phys. Rev. Lett. 106 (2011) 117002

**Solid state models and emergent relativistic symmetries**

**Vieri MASTROPIETRO (Roma 2 Univ.)**

Methods of Constructive QFT allow to quantitatively understand the exact relation between solid state lattice models and their effective QFT description. Even if irrelevant in the RG sense, lattice effects and nonlinear bands, breaking the relativistic symmetries of the effective descriptions, play a crucial role in the computation of several physical observables.
We discuss applications to
1) Extended 1D Hubbard models;
2) Hubbard models on the honeycomb lattice;
3) A lattice gauge theory for graphene

**Thermodynamic Study for Large Flavor QCD and Conformal Window**

**Kohtaroh MIURA (LNF INFN)**

The subject of this presentation is the chiral phase transition at finite temperature (T) and the emergence of the conformality in the color SU(Nc=3) gauge theory with many flavors (Nf) of fundamental fermions.
We aim at clarifying the chiral phase transition line in T-Nf plane, where the loss of a chiral phase transition at finite T with increasing Nf indicates the emergence of a conformal phase.
The status of this attempt is clarified in the review of several types of QCD phase diagrams and the Miransky scaling.
We provide the first staggered-based study for the finite T chiral phase transition at Nf = 6 with a confirmation of the asymptotic scaling low.
Combining this result with the other Nf results, we investigate the Miransky-Yamawaki (MY) phase diagram and the T-Nf diagram by using the lattice Lambda as a common ruler.
The thermal chiral transition in Nf = 0 – 8 seems to be connected to the bulk transition at Nf = 12 in the MY phase diagram.
At Nf = 8, Tc/Lambda becomes significantly larger, and we discuss its interpretation and relation to the nealy conformal dynamics.

## Fractional topological insulators

**Christopher MUDRY (PSI)**

The field of topological band insulators/superconductors was born with the discovery of the integer quantum Hall effect.
In the last 6 years, it was predicted that topological band insulators and superconductors exist in five different incarnations for any dimension of space.
This prediction has been verified experimentally in two and three dimensions for the so-called $\mathbb{Z}^{\ }_{2}$ topological band insulators.
The fractional Hall effect realizes an even more exotic state of matter. I will discuss some conditions under which fractional topological insulators can arise in lattice models for fermions.

**Seeing topological order**

**J. PACHOS (Leeds Univ.)**

Different phases of matter can be distinguished by their symmetries. This information is captured by order parameters that summarize the essential properties of the phase. Order parameters are usually defined in terms of local operators that can be measured in the laboratory. Topological insulators are materials with symmetries that depend on the topology of the energy eigenstates of the system. These materials are of interest because they can give rise to robust spin transport effects with potential applications ranging from sensitive detectors to quantum computation . However, direct measurement of topological order has been up to now impossible due to its non-local character. In this talk we provide a general methodology to perform a direct measurement of topological order in cold atom systems. As an application we propose the realisation of a characteristic topological model, introduced by Haldane, using optical lattices loaded with fermionic atoms in two internal states. We demonstrate that time-of-flight measurements directly reveal the topological order of the system in the form of momentum space skyrmions.

**Probing the topological exciton condensate via Coulomb drag**

**Marco POLINI (SNS)**

The onset of exciton condensation in a topological insulator thin film was recently predicted [1]. In this talk [2] I will discuss calculations of the critical temperature for this transition, taking into account screening effects.
Furthermore, I will demonstrate that the proximity to this transition can be probed by measuring the Coulomb drag resistivity between the surfaces of the thin film as a function of temperature.
This resistivity shows a logarithmically-large upturn upon approaching the exciton-condensed state.

[1] B. Seradjeh, J. E. Moore, and M. Franz, Phys. Rev. Lett. 103, 066402 (2009)
[2] M. P. Mink, H. T. C. Stoof, R.A. Duine, M. Polini, and G. Vignale, arXiv:1108.2298.

**Anderson localization through Polyakov loops: lattice evidence and random matrix model**

**Sebastian SCHIERENBERG (Regensburg Univ.)**

We investigate low-lying fermion modes in SU(2) gauge theory at temperatures above the phase transition. Both staggered and overlap spectra reveal transitions from chaotic (random matrix) to integrable (Poissonian) behavior accompanied by an increasing localization of the eigenmodes. We show that the latter are trapped by local Polyakov loop fluctuations. Islands of such "wrong" Polyakov loops can therefore be viewed as defects leading to Anderson localization in gauge theories. We find strong similarities in the spatial profile of these localized staggered and overlap eigenmodes. We discuss possible interpretations of this finding and present a sparse random matrix model that reproduces these features.

**Topological semimetals: from Standard Model to flat band**

**G. VOLOVIK**

Topological media are systems whose properties are protected by topology, and thus are robust to deformations and generic. Examples are topological superconductors, topological insulators, topological semimetals, graphene, superfluid phases of 3He, and even quantum vacuum of Standard Model of elementary particles. These systems may exhibit quantization of physical parameters, such as quantized spin Hall conductivity, and have exotic excitations living on the edge of atopological systems, such as Majorana fermions. We discuss the topological semimetals - substances intermediate between insulators and metals. Instead of the metallic Fermi surface they have the Dirac points or Dirac lines -topologically protected point nodes or nodal lines in the spectrum of electrons. An example of semimetals with point nodes is the vacuum of Standard model, while an example of semimetals with nodal lines is a metastable form of graphite with a rhombohedral stacking of graphene layers. The unique property of a semimetal with nodal lines in bulk is that its surface contains electrons without dispersion: all electrons within such a flat band on the surface have exactly zero energy. This property crucially influences the critical temperature of the superconducting transition. While in all the known superconductors the transition temperature is exponentially suppressed as a function of the pairing interaction, in the flat band the transition temperature is proportional to the pairing interaction, and thus can be essentially higher. Search for or artificial fabrication of such semimetals may thus open the route to room-temperature superconductivity.