GRAPHENE AND 2DM VIRTUAL CONFERENCE & EXPO

Graphene online 2020
October 19-23

GRAPHENE AND SUPERSYMMETRY

ANTONIO GALLERATI

GRAPHENE: suitable framework to study what is believed to be, as close as possible, a quantum field in a curved space-time:

- consistent description of its electronic properties in terms of Dirac pseudoparticles;
- quasi-relativistic particle behavior observed at sub-light speed regime;
- possibility of new, direct observation of quantum behavior in the curved background of a solid state system.

Open mass gaps: Haldane model [1]

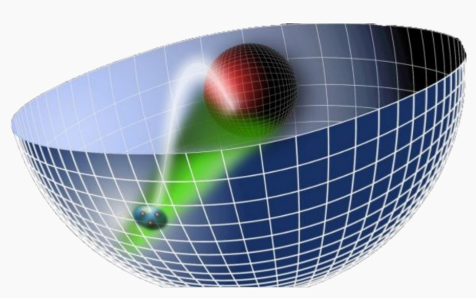
$$H = H_0^{(\mathrm{t.b.})} + t \sum_{\langle i,j\rangle_2} e^{i\,\varphi\,\alpha_{ij}}\, c_i^\dagger\, c_j \,+\, \epsilon_i\, M \sum_i c_i^\dagger\, c_j \;.$$

- Second-neighbor hopping terms with unimodular phase factor, the phase sign depending on the 'chirality' of the electron path.
- Parity breaking terms spoiling sublattices equivalence.
- Different fermion masses in the two inequivalent valleys:

$$m_{\mathbf{K}} = M - 3\sqrt{3}\, t_2\, \sin\varphi\,, \qquad m_{\mathbf{K}'} = M + 3\sqrt{3}\, t_2\, \sin\varphi$$

HOLOGRAPHIC CORRESPONDENCE

Infer properties of a strongly coupled D-1 dimensional quantum model defined at the boundary from a classical D dimensional (AdS) gravity theory living in the bulk.



- At low energy there is a one-to-one correspondence between quantum operators at the boundary and fields of the bulk gravity theory;
- Boundary conditions for gravity fields in D dimensions act as sources for operators of the D-1 dimensional quantum conformal field theory.

Target: write down a D=4 gravity model whose D=3 boundary features an effective theory for a spin ½ fermion defined on a curved geometry.

- Check if the spin ½ fermion can be identified with Dirac electronic charge carriers).
- Look at the possible mechanisms to describe a mass gap.

AVZ MODEL [2,3]

Construct a N-extended supersymmetric gravity model with AdS$_4$ vacuum supergroup $\mathrm{OSp}(\mathrm{p},2)_+ \times \mathrm{OSp}(\mathrm{q},2)_-$ with $p+q=N$:

- the boundary is reached in the $r\to\infty$ limit, where the leading term of the D=4 vielbein $E^i_\pm$ is written in terms of the D=3 vielbein e^i :

$$E^i_\pm \;=\; \pm\,\frac{1}{2}\left(\frac{r}{\ell}\right)^{\pm1} f(\chi)\;e^i \;+\; \dots\;;$$

- the torsion can be written as

$$T^i_\pm \;=\; D_\Omega\, e^i \;=\; \beta\, e^i + \tau_\pm\, \varepsilon^{ijk}\, e_j \wedge e_k$$

with $\tau_\pm = \tau \mp 2\,\frac{f}{\ell}$;

- the Dirac equation has the form:

$$\not{D}\chi_\pm = -\frac{3}{2}\, i\, \tau_\pm\, \chi_\pm \quad\Longrightarrow\quad m_\pm = \frac{3}{2}\tau_\pm$$

If we describe the single electron wave function of graphene in terms of a two-component Dirac spinor:

- the fermions of the theory may describe charge carriers in graphene at the Dirac points **K**, **K'**;
- fermion masses depend on the geometry (torsion) of the three-dimensional spacetime: $m_\pm = \frac{3}{2}\tau_\pm$
- well-established *top-down approach*, in that the D=3 effective theory derived at the boundary originates from a well-defined effective supergravity in the bulk;
- it is possible to generate Semenoff and Haldane-type effective masses:

$$m_\pm = \frac{3}{2}\,\tau_\pm = \frac{3}{2}\,\tau \mp 3\,\frac{f}{\ell} \quad\Longleftrightarrow\quad m_{\mathbf{K},\mathbf{K}'} = M \mp 3\sqrt{3}\, t_2\, \sin\varphi$$

CONTACT PERSON

antonio.gallerati@polito.it

REFERENCES

[1] F. D. M. Haldane, Phys. Rev. Lett. 61 (1988) 2015

[2] Alvarez, Valenzuela, Zanelli, JHEP 04 (2012) 058

[3] Andrianopoli, Cerchiai, D'Auria, Gallerati, Noris, Trigiante , Zanelli, JHEP 01 (2020) 084

Graphene online 2020