Theoretical Physics

Nuclear structure and nuclear reactions in low energies

New developments in radioactive beam acceleration and large detector arrays have allowed, not only the study of new nuclear systems, but also a much better knowledge of some spectroscopic observables. Hence, there are new possibilities to develop and test many body techniques applying in some cases previously developed solutions to new systems.

Since the nuclear stability line departs from $N \approx Z$ for $A > 40$, previous detailed spectroscopic studies of those type of nuclei had been performed in lighter systems. This can be and is being studied using shell model techniques, either with large scale calculations or schematic models based in group theoretical classifications as well as within a collective description of the relevant degrees of freedom.

Some phenomena related to octupole or tetrahedral degrees of freedom are more noticeable at the onset of quadrupole deformation regions. We are using our experience on these types of excitations to find a relation between the relative influence of the T=1 and T=0 channels of the nuclear interaction, the effects of octupole components in the deformed systems and the alpha-like correlations.

It has been possible to study the thermal character of giant resonances built on top of nuclear excited states. From the experimental data of giant dipole resonances results an excess of low energy photons, which is at odds with the predictions of simple models.

The existence of neutron skin in neutron reach nuclei has been studied in connection with the excitation of isovector dipole and quadrupole giant modes via isoscalar nuclear probes. In the case of large neutron excess, important contributions are obtained for the nuclear excitation and constructive interference is found between nuclear and Coulomb contributions.

Chaos and complex systems

Quantum Maps. Quantum maps provide the simplest, yet highly non-trivial, arena for the investigation of the quantum properties of chaotic systems. As simple models of Poincaré sections of realistic Hamiltonians or of time dependent "kicked" systems, they provide a testing ground for semiclassical approximations, correlations, universalities, localization, etc. We have developed techniques for the construction, semiclassical behaviour and phase space description of the baker's map, the Smale horseshoe, cat maps, etc.

Quantum Billiards. Billiards in 2-D provide some of the best realistic models where wave and particle behaviour can be studied and related. Besides their intrinsic theoretical interest they describe the behaviour of ballistic electrons in mesoscopic cavities or of light in optical microcavities. The group has studied extensively the highly excited spectrum of plane chaotic billiards and its semiclassical description in terms of periodic orbits. A very efficient "scaling" method for the precise calculation of very excited eigenstates has been developed, which is now the best available. A theory of short periodic orbits is under active development with aim of taming the exponential increase in the number of periodic orbits needed for the semiclassical description of spectral properties.

Quantum Algorithms. Studies of quantum algorithms viewed as quantum maps. Thus, we can apply semiclassical techniques, phase space analysis, and long time behaviour characteristics of quantum maps to the operation of quantum circuits, providing a novel approach in this area.

Transport Phenomena in Mesoscopic Systems. Application of the general methods of chaotic dynamics to the study of mesoscopic systems. We have studied persistent currents and the effects of surface roughness in ballistic cavities and the statistical properties of the fluctuations in the total energy in a non-interacting fermion system.

Chaotic Scattering at the Nuclear Coulomb Barrier. There are interesting and characteristic anomalies in the heavy ion cross sections and angular distributions at backwards angles that can be interpreted as arising from chaotic scattering due to the coupling of intrinsic and translational degrees of freedom at Coulomb barrier energies. We have modeled these processes and proposed experiments to test these characteristics.

Field theoretical methods in strongly interacting systems

Nuclear structure problems related to the description of the double beta decays have been investigated. Special attention was paid to the difficulties related to the treatment of the zero modes associated to the breaking of isospin symmetry. For this purpose a formalism based on the use of BRST symmetry was developed.

The spectrum of the 70^- baryon resonances has been investigated using the large N_c expansion of QCD.

Some properties of the QCD chiral phase transtion at finite temperature and chemical potential using non-local extensions of chiral quarl models. We have made predictions for the position of the “tricritical point” (chiral limit) and the “end point” and the phase diagram in the temperature density phase.

The problem of the center of mass in many-body nuclear systems has been revisited. Once the counter terms needed to satisfy translational invariance were determined, collective variables have been introduced. The problems associated with the overcompleteness and divergencies were solved using BRST invariance. The formalism has been applied to the calculation of some electroweak operators relevant to muon-electron conversion process.

Another topic, which has been extensively studied, is that of nuclear microscopical models and approximations in connection to their use in predictions for observables in exotic electroweak processes such as double beta decay.

Investigations concerning the edge states in the fractional Quantum Hall Effect. In particular, different predictions of the two classes of theories currently used to describe these states have been studied. We have also considered a Chern-Simons theory in 2+1 dim to describe the quasiparticles in the Pfaffian states.

Inhomogeneous Quantum Fluids

The investigation of the structure and stability of helium systems is the object of many theoretical and experimental works. Mainly two different theoretical approaches for investigating helium systems have been successfully employed in the literature:

A self-consistent variational formalism based on the use of interatomic potentials within the framework of the theory of correlated basis functions in conjunction with the hypernetted chain expansion, and,

A semiphenomenological approach which uses a density functional. In this semiphenomenological description the energy of the systems is written in terms of a functional depending of the density.Among the properties of inhomogeneous superfluid ^{4}He, we have mainly studied the stability of helium films. This feature is determined by variational properties of the chemical potential μ which is introduced in order to impose the conservation of the particle number N when solving the equation for the density profile, and by the requirement of a negative surface tension.

The behavior of films adsorbed onto solid planar substrates of alkali metals has been studied. The calculations were carried out by using the density functional formalism. Results indicate that the surface of Rb is not wetted by ^{4}He at T=0 K.

Now, we are focusing our attention on helium systems with cylindrical geometry. In this case a stability criterion consistent with basic equations of the thermodynamics was derived.

“Global Phase Time and Path Integral for String Cosmological Models”

C. Simeone , G. Giribet

*Modern Physics Letters **A16** (1) (2001) 19*

A global phase time is identified for homogeneous and isotropic cosmological models yielding from the low energy effective action of closed bosonic string theory. When the Hamiltonian constraint allows for the existence of an 0intrinsic time, the quantum transition amplitude is obtained by means of the usual path integral procedure for gauge systems.

“Temperature antipairing effect over the Energy Weighted Sum Rule”

E.C. Seva, A. Tonina y H.M. Sofia

*Nucl. Phys. **A686** (2001) 241-257*

We study the temperature dependence of the sum rules using the discontinuity of the first derivative of the Matsubara Green's functions of a bilinear particle-hole operator. Particularly we study the behavior of the dipole particle-hole operator. We applied the calculation to ^{114}Sn, ^{138}Ba, ^{154}Gd and ^{170}Yb. It is found that the energy weighted sum rule for the dipole operator changes as a function of the temperature depending on the square of the gap. This fact is related to the antipairing effect of the temperature over the nuclear system.

Prompt Emission of Dipole Radiation in Nuclear Reactions with Radioactive Beams”

C. H. Dasso, H. M. Sofia, A. Vitturi

The European Physical Journal A12 (2001) 279-284

Radioactive beams expand considerably the range of reactions with a large charge-to-mass asymmetry between projectile and target that can be probed experimentally. We introduce a simple model to estimate the magnitude and energy distribution of the prompt dipole gamma-emission that takes place while the symmetry is restored during the short contact time. In addition to this pre-equilibrium component we also introduce a procedure to calculate the delayed gamma-emission of statistical character that occurs after thermal equilibration of the compound system, or the binary reaction ejectiles, is reached.

“Semiclassical Construction of Resonances with Hyperbolic Structure. The Scar Function”

E. Vergini and G. Carlo

*J. Phys. **A34** (2001) 4525-4552*

The formalism of resonances in quantum chaos is improved by using conveniently defined creation-anihilation operators. With these operators at hand, we are able to construct transverse excited resonances at a given Bohr-quantized energy. Then, by requiring minimum energy dispersion we obtain solutions in terms of even or odd transverse excitations. These wave functions, which are constructed in the vicinity of a periodic orbit with maximum energy localization, provide a precise definition of *scar function*. These scar functions acquire, in the semiclassical limit, the hyperbolic structure characteristic of unstable periodic orbits.

“Localization Properties of Groups of Eigenstates in Chaotic Systems”

D. Wisniacki, F. Borondo, E. Vergini and R. M. Benito

Phys. Rev. ***E63*** *(2001) 066220*

In this paper we study in detail the localized wave functions defined in Phys. Rev. Lett. 76, 1613 (1994), in connection with the scarring effect of unstable periodic orbits in highly chaotic Hamiltonian systems. These functions appear highly localized not only along periodic orbits but also on the associated manifolds. Moreover, they show in phase space the hyperbolic structure in the vicinity of the orbit, something that translates in configuration space into the strcture induced by the corresponding self-focal points. On the other hand, the quantum dynamics of these functions are also studied. Our results indicate that the probability density first evolves along the unstable manifold emanating from the periodic orbit, and localizes temporarily afterwards on only a few, short related periodic orbits. We believe that this type of study can provide some keys to disentangle the compolexity associated with the quantum mechanics of these kind of systems, which permits the construction of a simple explanation in terms of the dynamics of a few classical structures.

“Quantum Spectra of Triangular Billiards on the Sphere”

M.E. Spina, M. Saraceno

J. Phys. ***A34*** *(2001) 2549*

We study the quantal energy spectrum of triangular billiards on a spherical surface. Group theory yields analytical results for tiling billiards while the generic case is treated numerically. We find that the statistical properties of the spectra do not follow the standard random matrix results and their peculiar behaviour can be related to the corresponding classical phase space structure.

“Chiral Phase Transition in a Covariant Nonlocal Nambu-Jona-Lasinio Model”

I. General, D. Gómez Dumm and N.N. Scoccola

Phys. Lett. ***B506*** *(2001) 267*

The properties of the chiral phase transition at finite temperature and chemical potential are investigated within a nonlocal covariant extension of the Nambu-Jona-Lasinio model based on a separable quark-quark interaction. We consider both the situation in which the Minkowski quark propagator has poles at real energies and the case where only complex poles appear. In the literature, the latter has been proposed as a realization of confinement. In both cases, the behaviour of the physical quantities as functions of T and m is found to be quite similar. In particular, for low values of T the chiral transition is always of first order and, for finite quark masses, at certain “end point” the transition turns into a smooth crossover. In the chiral limit, this “end point” becomes a “tricritical” point. Our predictions for the position of these points are similar, although somewhat smaller, than previous estimates. Finally, the relation between the deconfining transition and chiral restoration is also discussed.

“Strange Multibaryons in Topological Soliton Models”

N.N. Scoccola

Proc. "VII International Conference on Hypernuclear and Strange Particle Physics" Italia, 2000, Nuclear Physics ***A691*** *(2001) 399*

We report on a study of strange multibaryon systems in the context of SU(3) topological soliton models. In particular we describe how to compute the spectra of the low-lying states with baryon number *B £ 8*. Using the masses obtained in this type of calculations we discuss the stability of some *S=-B* configurations, like e.g. the H-dibaryon.

“Non-leptonic hyperon weak decays in the Skyrme model revisited”

D. Gomes Dumm, A.J. García, N.N. Scoccola

Proc. “Hadrons Physics 2000”. Brasil, Ed. F. S. Navarra et al. (World Scientific, Sigapore, 2001) pp. 310

Non-leptonic hyperon weak decays are investigated in the SU(3) Skyrme model. We follow a collective coordinate scheme in which the symmetry breaking terms in the strong effective action are diagonalized exactly. To describe the weak interactions we use an octet dominated weak effective lagrangian that leads to a good description of the known 2p and 3p kaon decays. We show that the observed S-wave decays are reasonably well reproduced in the model. On the other hand, our calculated P-wave amplitudes do not agree with the empirical ones even though both pole and and contact contributions to these amplitudes are properly taken into account.

“Chiral Phase Transition in a Covariant Nonlocal Nambu-Jona-Lasinio Model”

I.General, D. Gómez Dumm y N.N. Scoccola

Proceedings of “Workshop on Dynamical Aspects of the QCD Phase Transition”, Trento, Italy. March 12-15, 2001. Rostock 2000/Trento 2001, Exploring Quark Matter, pp.183-193 (nucl-th/0111014)

The properties of the chiral phase transition at finite temperature and chemical potential are investigated within a nonlocal covariant extension of the Nambu-Jona-Lasinio model based on a separable quark-quark interaction. We consider two types of non-local regulators: a gaussian regulator and the instanton liquid model regulator. In the first case we study both the situation in which the Minkowski quark propagator has poles at real energies and the case where only complex poles appear. We find that in all the cases the behaviour of the physical quantities as functions of T and m is quite similar. In particular, for small values of T the chiral phase transition is always of first order and, for finite quark masses, at certain “end point” the transition turns into a smooth crossover. Predictions for the position of this point are presented.

“Effective chern-simons theories of pfaffian and parafermionic quantum hall states, and orbifold conformal field theories”

E.H. Fradkin, M. Huerta, G.R. Zemba

*Nucl.Phys.**B601**, (2001) 591-606 (e-Print Archive: cond-mat/0011143)*

We present a pure Chern-Simons formulation of families of interesting Conformal Field Theories describing edge states of non-Abelian Quantum Hall states. These theories contain two Abelian Chern-Simons fields describing the electromagnetically charged and neutral sectors of these models, respectively. The charged sector is the usual Abelian Chern-Simons theory that successfully describes Laughlin-type incompressible fluids. The neutral sector is a 2+1-dimensional theory analogous to the 1+1-dimensional orbifold conformal field theories. It is based on the gauge group O(2) which contains a $\mathbf{Z}_2$ disconnected group manifold, which is the salient feature of this theory. At level q, the Abelian theory of the neutral sector gives rise to a $\mathbf{Z}_q$ symmetry, which is further reduced by imposing the $\mathbf{Z}_2$ symmetry of charge-conjugation invariance. The remaining $\mathbf{Z}_q$ symmetry of the neutral sector is the origin of the non- Abelian statistics of the (fermionic) q-Pfaffian states.

“Structure and stability of superfluid ^{4}He systems with cylindrical symmetry”

L. Szybisz, S.M. Gatica

*Phys. Rev. **B64** (2001) 224523*

The structure and stability of superfluid ^{4}He systems with cylindrical symmetry are studied. Ground-state energies and density profiles are computed by using density functional approaches. A model to understand the energetics of cylindrical systems is developed by following the main ideas of the Droplet Model utilized to describe spherical clusters. The necessary condition for stability is formulated by imposing a positive longitudinal isothermal compressibility along the principal axis of the cylinder. It is shown that free cylinders of ^{4}He at T=0 K are unstable. As an example of the evolution towards stable systems results for liquid ^{4}He confined by cylindrical nanopores in Cs are reported.