PROPOSAL FOR A COST ACTION

ACTION TITLE AND ACRONYM

EMERGENT BEHAVIOUR IN CORRELATED MATTER

Acronym: ***ECOM***

PRINCIPAL APPLICANTS:

Professor Dr. ***E. Bauer***[1], *Institute of Solid State Physics, Vienna University of Technology, A-1040 Wien, Austria*

Professor Dr. ***H. von Löhneysen***, *Institute of Physics, Universität Karlsruhe, D-76131 Karlsruhe, Germany*

Professor Dr. ***M. Sigrist***, *Institute for Theoretical Physics, ETH Zürich, CH-8093 Zürich, Switzerland*

COST National Co-ordinator (Austria):

Prof. Dr. Reinhard FOLK, Institut für Theoretische Physik der Universität Linz,
A-4040 Linz, Austria

[1] Contact person

A) Background:

Research on materials with strongly correlated electrons has become one of the most vital topics in condensed matter physics. This fact relates to the discovery of unexpected features and phases of metals and Mott-insulators found among intermetallic and oxide compounds at low temperatures. Among the diverse aspects of the physics of strongly correlated electron systems quantum phase transitions and related quantum critical phenomena are of particular importance. Quantum critical fluctuations can lead to strong renormalization of normal metal properties as well as to novel exotic phases emerging from these strongly fluctuating environments. As a result, many groups in Japan, USA and Europe have focused their activities to these topics.

Recent breakthroughs in the field of systems having strong electron correlations were basically made in Europe, e.g., the possibility of a real non-Fermi liquid (NFL) phase stabilised by pressure and temperature, the discovery of superconductivity in the presence of ferromagnetic fluctuations, the coexistence of heavy fermion (HF) superconductivity (SC) with long range magnetic order at ambient conditions, or the observation that HFs can fractionalize into a component carrying electrical current and in another carrying the magnetic degrees of freedom. The most recent discovery concerns the first HF SC lacking a inversion centre.

The standard description of metals relies on the Fermi-liquid (FL) theory of Landau based on the quasi-particle concept that has provided a remarkable robust paradigm for describing physical properties at low temperatures [1]. The main predictions of the FL theory are that well below a characteristic temperature, T_F, the resistivity should exhibit quadratic temperature dependence, the heat capacity should show a linear temperature dependence and the magnetic susceptibility should be temperature independent. These predictions for systems without broken symmetries have been borne out in many metals and HF systems and seemed ubiquitous until the previous decade when experiments demonstrated that exceptions indeed exist in some HF compounds, transition metal alloys and oxides, including high-Tc superconductors, quantum dot and organic charge-transfer systems [2-4]. This growing family of materials show physical properties significantly deviating from the prediction of FL theory at low temperatures, the so-called NFL behaviour: the heat capacity behaves like $-T\ln T$, the resistivity exhibits a T^n ($1 \leq n \leq 2$) dependence, and the magnetic susceptibility varies as $1-T^{1/2}$ or $-\ln T$. Many of these systems share the property that they are in the proximity of a *quantum phase transition* (QPT) or a *quantum critical point* (QCP) [5]. Approaches alternative to the QPT scenario, proposed to explain NFL features are based on the theory of specific disordered systems and of multi-channel or quadrupolar Kondo models [6].

Quantum phase transition is a zero temperature, in most cases second order, phase transition between, usually, magnetic and nonmagnetic states driven by a control parameter such as pressure, magnetic field, or composition/chemical-pressure, which regulate the amplitudes of the quantum fluctuations. In a metal near the QPT there are large amplitude fluctuations in the Fermi surface area and a divergence of the quasi-particle mass. It is now generally acknowledged that these quantum fluctuations, instead of thermal fluctuations, influence the physical properties of correlated electron systems even at elevated temperatures [5]. This results from the uncertainty principle, i.e., the energy scale of fluctuations introduces a time scale, which leads to an intricate coupling of static and dynamic critical behaviour.

Most of the concepts and phenomenological models developed in this field were successfully applied to systems like $CeCu_{6-x}Au_x$, one of the early examples exhibiting a QPT at a critical concentration $x_c \approx 0.1$, where long-range incommensurate antiferromagnetic order vanishes [6]. Microscopically, however, the fate of the conduction electrons, more precisely quasi-particles, at such a QPT is largely unknown. It is in this realm that the standard model of electrons in metals fails completely. At present, there are two theoretical scenarios available neither of which is able to explain in detail the experimental observations: The more traditional Hertz-

Millis-Moriya picture assumes that quasi-particles undergo singular scattering at the quantum critical point due to the abundance of low-lying magnetic fluctuations [7]. This leads to a diverging mass for ferromagnets and two-dimensional antiferromagnets where singular scattering is possible on the entire Fermi surface. The other - more radical approach - postulates a break-down of the quasi-particle concept altogether at the QCP, emphasizing their composite nature due to the local hybridization of the 4f-electrons and the conduction electrons [8,9]. This would imply the collapse of the whole Fermi surface and the emergence of local physics (local quantum criticality).

The QPT concept leads very naturally to one of the key attributes of the normal state physics, namely, that the energy scale governing spin and charge fluctuations is the temperature itself, a property labelled as *E/T-scaling* behaviour of the dynamical susceptibility [10]. This *E/T*-scaling has been observed in high-T_c SC as well as in NFL HF systems, such as $U(Cu,Pd)_5$ [11], $Ce(Cu,Au)_6$ [12] and very recently Ce(Rh,Pd)Sb [13]. In studies of *E/T*-scaling by neutron scattering the dynamical susceptibility reveals different scaling exponents, ~0.33 for $U(Cu,Pd)_5$ and ~0.75 for $Ce(Cu,Au)_6$ and Ce(Rh,Pd)Sb. Scaling, however, breaks down above a critical temperature or frequency, marking the typical energy scale of the system [13].

An even more exciting feature is the observation that in the proximity to a QPT unconventional forms of SC occurs. Well-known examples are the high-T_c and HF SC $CeCu_2Si_2$, $CePd_2Si_2$ [14], UGe_2 [15], or $CeTIn_5$ (T=Co, Ir) [16], where SC occurs very close to the QCP in the phase diagram. For most of these materials, there are strong indications that pairing is caused by electron correlations, in contrast to conventional SC such as Pb, Nb, etc. Non-phononic mechanisms of pairing are believed to favour a non-trivial symmetry of the Cooper pairs. For example, the order parameter in the high-T_c SC, where the pairing is likely caused by the antiferromagnetic correlations, has the d-wave symmetry with lines of zeroes in the quasi-particle at the Fermi surface. Such lines of zeroes were revealed for some of the HF SC as well.

B Objectives and Benefits

The main objective of this action is to provide an **essential** contribution to knowledge and development in the various fields of strongly correlated electron systems via a concerted European effort. Basic research in this area requires the co-operation of a large number of scientists from various fields.

Our aim is to study experimentally as well as theoretically correlated systems which possess complex interactions between many degrees of freedom, in order to find new phases of matter. On the experimental side a strong effort in the production of high-quality materials and samples will be the fundament of successful studies. These include mainly d- and f-electron systems, intermetallic and oxide compounds in various forms, polycrystalline and single crystals as required, amorphous or in artificially layered structures. Studies of materials in diverse forms are expected to shed new light different quantum phases, on order-disorder phenomena, on the issue of effective dimensionality as a function of various external parameters, such as temperature, pressure or doping. The understanding of the complex phase diagrams and the underlying physic of strongly correlated electron systems is the basis for future applications in electronic devices and sensors or large-scale facilities as electric power transmission and control.

A larger number of challenges have to be coped with. These include the identification of order parameters and pairing mechanisms of unconventional superconductors in the growing number of newly discovered superconducting strongly correlated electron systems. A further important task to be tackled is concerned with the distinction between the two major theoretical scenarios describing the physics in the proximity of a quantum critical point: the Hertz-Mills-Moriya theory and the composite-electron theories based on fractionalization of electronic degrees of freedom. This implies in addition a clear characterization of the non-Fermi-liquid behaviour which provide insights into one important aspect of quantum criticality.

A number of diverse experimental techniques will be employed in this endeavour, various spectroscopic techniques, such us neutron scattering (including spectroscopy of magnetic and lattice excitations), tunnelling spectroscopy, muon-spin-resonances measurements or various optical measurements. Transport and thermodynamic measurements, such as resistivity, Hall effect, heat transport, thermoelectric effects or specific heat and thermal expansion represent further ways to probe the physical behaviour of materials. The great advantage of a large-scale collaboration of this kind, is the opportunity to exchange samples which have been characterized and measured by various techniques and so avoiding wrong conclusions due to sample variety which is often unavoidable in forefront basic material science.

The role of the theory part besides accompanying the experimental efforts, lies in the development of new tools and concepts to address the important fundamental questions. The break-down of the standard Fermi liquid model in many strongly correlated electron systems has since many years posed one of the biggest challenges in the theoretical physics. Concepts concerning quantum phase transitions have to be extended, as several recent experimental results suggest. Beyond this there are many open questions concerning the quantum phases themselves, in particular, quantum liquids of various kinds of degrees of freedom which represent the basic fundament (“vacuum”) on which new physical phenomena appear. Theorists have also the task to propose new tests for theoretical concepts. ECOM involves many groups with well spread expertise so that different viewpoints may melt together to fruitful novel concepts.

A further important aspect of ECOM is the fact, that many Eastern European teams will be involved, providing access to the strong expertise in these countries and at the same time integrating them into the greater European effort in this field. Many of these Eastern European research groups are actually relying on support via program to have a contact to Western European labs.

Finally also the educational aspect has be kept in mind, as our activity will include the exchange and the training of graduate students and postdoctoral fellows.

Overall the goal of ECOM is maintain and enhance further the leading role the European science community plays in this rapidly developing field of strongly correlated electron systems and to ensure that European research group remain competitive with the USA and Japan.

C. Scientific Programme

The complexity of basic research on metal properties requires the co-operation of scientists from various fields including material chemists, solid state physicists and theoreticians, and additionally needs the involvement of large scale facilities as well. The exploration of novel features and phenomena, largely related to macroscopic quantum phases, can be successful only if concerted actions are taken such as co-operations under the umbrella of COST.

At present, we intend to direct research in terms of the proposed action towards

- **Superconductivity:** i) interplay of superconductivity and magnetic order, e.g., $CeTMIn_5$, $CePt_{3-x}TM_xSi_{1-y}X_y$ (TM = transition element, X = Ge, Sn …), UGe_2, $ZrZn_2$, ε-Fe, $CeCu_2Si_2$, $(U,Th)Be_{13}$; ii) pairing symmetry, e.g., $CeTMIn_5$, $CePt_3Si$, UGe_2, $ZrZn_2$, ε-Fe, $CeCu_2Si_2$, $(U,Th)Be_{13}$, $PrOs_4Sb_{12}$; iii) novel materials: e.g. $Na_xCoO_{4-y}H_2O$, $(U,Th)B_2C$.
- **Magnetism:** i) novel quantum critical phenomena, e.g. $Sr_3Ru_2O_7$ (quantum critical endpoint-induced metamagnetism, ii) field induced quantum phase transitions, e.g., Bose-Einstein condensation of magnons in dimer systems such as $TlCuCl_3$, $KCuCl_3$, $SrCu_2(BO_3)_2$ iii) magnetic properties of doped magnetic insulators, iv) orbital antiferromagnetism and toroidal magnetism, v) frustrated magnetism.

- **Spin-Orbital Physics:** various forms of combined spin and orbital order and spin and orbital quantum liquid phases, e.g, vanadates, manganates, titanates, pyrochlores.
- **Exotic Metallic and Non-metallic Compounds:** strongly renormalized FL behaviour in HF systems, behaviour of the Fermi surface at quantum phase transitions, NFL behaviour close to quantum phase transitions, metal to insulator transition, narrow gap and Kondo semiconductor.
- **Transport:** heat, charge and spin transport in homogeneous and inhomogeneous systems with strong correlations.
- **Thermopower:** study of long-lived spin fluctuations induced by local electron interactions; thermopower enhancement in Kondo insulator at low temperatures.
- **Magneto Thermal effects:** correlated electron systems on the border of QPT can exhibit enhanced magneto-caloric effects; they can provide high conductivity and high spin-density alternatives to conventional magnetic cooling salts for the miniaturization of low temperature refrigerators.
- **Theory:** mechanisms of pairing and order parameter of unconventional SC; study of quantum critical phenomena beyond the single-band (Hertz-Millis) scheme and development of alternative approaches. Theoretical support of experimental studies above.

<u>Working Group1:</u>

Novel materials:

Many of the already discovered features of systems with strong electron correlations were made on bulk materials of outstanding quality. However, the influence of the dimensionality of the system, the structure - ranging from the nanocrystalline scale to large single crystals – and dynamic inhomogeneities are still largely unexplored. One objective of the proposed research is thus a detailed exploration of the influence of macroscopic material parameters (dimension, inhomogeneities, etc.) on the microscopic properties of correlated metals as well as their tuning via external parameters such as substitution, magnetic fields, hydrostatic pressure or hydrogenation.

The proposed COST action will help to co-ordinate sample preparation and distribution throughout the various participating groups. Improvement of sample quality due to exchange of knowledge and skills is one of the primary goals of the planned project. Many of the occurrences near to a quantum critical point are very sensitive to impurities in a specific material and unconventional superconductivity is even highly sensitive to nonmagnetic impurities. Thus, the synthesis of the various materials as indicated above with exceptional quality is a prerequisite of the proposed research. The successful investigation of novel materials starts, in general, with materials prepared in polycrystalline form, followed by single crystals and finally artificially prepared samples will help to address special questions. The latter may comprise thin- and thick films as well as structures prepared on a nano-size scale.

A significant portion of materials will be based on cerium, ytterbium and uranium. The common feature of these elements is a rather unstable 4*f*- or 5*f*-shell which, under certain circumstances, gives rise to structural, magnetic or superconducting instabilities, forming uncommon ground states. Temperature, doping, magnetic fields and hydrostatic pressure may favour such phase transitions and the weak magnetic moments of the above elements are preponderantly responsible for these instabilities in the proximity of zero temperature. There is a unique feature when comparing Ce and Yb compounds: both elements represent, because of the $4f^1$ and the $4f^{13}$ electronic configuration, an electron and hole analogue, respectively. Hence, pressure will shift such a system in an opposite manner across the QCP. Moreover, doping and substitution studies allow to influence the balance of the various interaction mechanisms, determining the a particular ground state. In the context of pressure, field and temperature dependent investigations, the appropriate phase diagram of a certain system can be established. The latter confines the phase space of the various forms of magnetic order, superconductivity or other characteristic temperatures.

Other groups of materials and phenomena which will be investigated throughout the proposed period of the COST action concern hidden magnetic order in systems like URu_2Si_2. By field tuning, this ternary compound and possibly $Sr_3Ru_2O_7$ exhibit novel phase(s) below the metamagnetic transition and near the QCP; an occurrence of two tricritical points is very likely. Of particular interest is the behaviour of correlated fermions in hosts with magnetic frustration. We will address the various forms of orbital ordering, giving rise to ferro- or antiferroquadrupolar ordering or even ordering with octupoles. We plan to investigate in detail narrow gap semiconductors (e.g., SmB_6) because closing the gap by pressure might establish a novel kind of QCP. Additionally, narrow gap semiconductors are promising candidates of correlated thermoelectrics. Nano-structuring of materials may open a “magic door” for novel physical features and interactions between nano-scaled clusters are a largely unexplored. Systems exhibiting electronic phase separation and superconductivity in materials with strong spin – orbit coupling and/or lacking a centre of inversion are other topical subjects within the proposed action.

Due to the diversity of materials foreseen in this research program, working groups will consist not of all participating groups; rather, an appropriate number of researchers with the relevant competence will attack a particular topic. The website, providing adequate information, will guarantee interested parties to join that task.

Working Group 2:

Experimental techniques:

The study of ground state properties of above indicated systems requires the use of well characterised samples in the diverse states. The initial characterisation of such materials may follow a number of standard procedures, including X-ray, elastic and inelastic neutron scattering, or electron-microprobe investigations.

The physical characterisation and the detailed study of low temperature properties will be carried out on the basis of macro- and microscopic probes. The former includes a variety of techniques like thermodynamic properties (susceptibility, magnetisation, specific heat), transport phenomena (electrical resistivity, thermal conductivity, thermopower). The latter comprises techniques like NMR, Moessbauer spectroscopy, L_{III} absorption edge spectroscopy, scanning tunneling microscopy and spectroscopy with in-situ nanofabricated, SC tips, muon-spin resonance (µSR) neutron scattering and optical measurements. All these techniques are available among the partners participating for a wide range of external parameters. This includes temperature (from the mK range to 1000°C), magnetic fields (up to 60 Tesla) and pressure (up to the 300 kbar range). The main emphasis in the experimental techniques will be given to an increase of resolution in the various techniques since phenomena near the quantum critical point exhibit very often small scales, requiring in general techniques and procedures which are well beyond average standard. One example in this respect concerns power laws emerging from low temperature measurements, where the exponent n appears to be a predominant quantity in the various theoretical calculations. The unambiguous determination of n is thus a basic requirement. The expertise available in the different groups participating in this European project is a valuable asset for a success of the proposed research.

Among the various techniques and parameters mentioned, hydrostatic pressure appears to be of outstanding importance. This refers to the fact that a tuning of physical properties across the quantum critical point cannot be made by temperature as is the case for finite-temperature phase transitions; rather, the typical control parameter is best represented by pressure as a “pure” thermodynamic quantity. Moreover, for controlled influencing intrinsic solid state properties and studying them without any disturbing disorder, high pressure in order to change interatomic distances is nearly unrivalled. State of the art pressure cells are well developed, but homogeneity of the pressure distribution inside the cell, the pressure range and the handling for the various experiments still need improvements. Again, expertise with respect to these tasks is available from the different groups of this project. Presently, within standard pressure techniques just a single physical quantity can be determined. A unique technique which has not yet been applied very often is the generation of uniaxial pressures, indispensable for the study of materials properties with respect to dimensionality problems.

Although the study of bulk properties of materials with strong electron correlations is, in general, the first step to be made in order to understand materials properties as well as the complex ground states, several microscopic techniques are additionally needed. The fact that magnetic moments are connected with the order parameter in the overwhelming number of materials under consideration, μSR experiments are a key technique, because the local-probe character of the muons make μSR very sensitive to spatially inhomogeneous magnetic properties. Hence the occurrence of different phases in a sample will be reflected by different components in the μSR signal, and a careful analysis of these components furnishes a direct measure of the fraction of the sample volume involved in a particular phase. The detection of magnetism characterized by extremely small values of the static moments in HF compounds is one of the main contributions of μSR to the investigation of HF phenomena. Other local probes like the $1/T_1$ relaxation rate of nuclear magnetic resonance (NMR) allows to gain information about SC order parameter in unconventional SC, Mößbauer studies will help to get rid of local magnetic fields and inhomogeneities in strongly correlated electron systems. Since all these latter techniques are contact-less measurements, more extreme conditions, e.g., pressure, can be applied. We aim to use expertise of the various groups (see also: *additional information*) to shift standard research conditions to the limits of available materials performance. To push instrumentation towards its limits often favour experimental breakthroughs in different experimental techniques, notably at extreme conditions. This may have impact on other domains of physics, e.g., geophysics.

Working group 3:

Theory and modelling:

The objectives of theoretical studies in this field are in most cases driven by experimental developments. This may sometimes lead the theoretical discussion into unforeseeable directions. Nevertheless, the long-term aim is the better understanding of the common concepts underlying the quantum phase transitions and phenomena related with it.

The physics of correlated electrons provides a ground for the study of novel SC phases with extraordinary properties. This includes time reversal symmetry violating phases with peculiar magnetic properties (observable in μSR experiments), chiral phases which might share some conceptional properties with quantum Hall systems, and the possibility to observe in a single material several SC phases analogous to superfluid ^{3}He, leading to complex SC phase diagrams. Another extraordinary feature is the interplay between SC and other ordered phases, in particular, magnetism. Sometimes it appears as a competition of the two states. In the other cases, SC may be a result of fluctuations of other incipiently ordered phases. Thus also the issue of mechanisms responsible for unconventional SC among which spin fluctuation exchange induced pairing has been the most advocated among many other possible mechanisms of this kind. Best known is the example of high-temperature SC where antiferromagnetic spin fluctuations in various descriptions represent a promising mechanism for the origin of Cooper pairing.

Quantum phase transitions involving itinerant electrons pose a problem of considerably higher complexity than that of localized degrees of freedom (spins or orbitals), and classical phase transitions, which are described by the Landau-Wilson approach, including only classical fluctuations. Ab initio methods and standard perturbative approaches fail to give reasonable results in most cases. In addition, the concepts of the Landau FL theory break down due to singular renormalizations of the electron properties. Novel concepts such as fractionalization of the electrons, e.g. spin-charge separation, have given surprising insights into possible origins of NFL behaviour. These are especially fruitful in the context of HF physics, where long standing problems like the question of “large” versus “small” Fermi surface have been revived. In which way localized degrees of freedom contribute to the Fermi sea of itinerant electrons and how the situation changes when passing through a quantum phase transition are some of the key questions.

The theory of NFL behaviour around a QPT or in other environments are in need of a systematic classification to trace their origins. What are necessary conditions to spoil the usually so robust quasi-particle properties of the FL concept? The experimental and theoretical effort within this project has to be seen on the background of these diverse open questions.

Working group 4:

Applications:

Local electron-electron correlations have a strong effect on spin, charge and energy transport in the various states of solids. Such materials are thus of a great scientific and technological importance, and their transport behaviour is of primary interest. New materials for thermoelectric and spintronic devices are thus the most specific targets in this field. Thermoelectric devices are reversible heat engines, and a change of entropy of the electron system transforms electric energy (sometimes even magnetic or elastic energy) into heat, or vice versa. While most current devices use semiconducting materials and can be operated efficiently only at high temperatures, strongly correlated materials could also work at very low temperatures. The reason is that the transition into the correlated ground state is often accompanied by giant thermoelectric power, as seen, e.g., in Kondo and valence fluctuating systems. However, an efficient device should not only have large electrical conductivity and thermopower but also low thermal conductivity, which is difficult to achieve in homogenous samples. Thus, attention will be directed towards heterostructures, phonon glasses, and other systems which may have a large thermoelectric performance (*figure of merit*), as required for successful applications. Interesting thermoelectric effects are also found when correlated systems are subject to an external magnetic field.

Spintronics is a new emerging field on the border between magnetism and electronics. Most current spintronic devices are based on magnetic tunnel junctions and on heterostructures with giant magnetoresistance. In these systems, and in new spintronic devices based on magnetic semiconductors, the response of the spin and energy currents to an external field or temperature gradient is of primary importance. All these systems are poorly understood and pose many difficult questions from the metallurgical, experimental and theoretical point of view. To acquire the knowledge and achieve control over the degrees of freedom relevant for the spin, charge and energy transport in correlated systems is thus a prerequisite.

The necessary tasks to reach proper understanding of the spin, charge and energy transport in inhomogeneous systems with strong correlation are a detailed physical characterization and tuning of intrinsic anisotropic properties and the theoretical modeling (e.g., Hubbard -, Anderson – or Falicov model) based on experimental results. Useful input for an understanding of such models can also be expected from the fast growing field of atomic physics in optical lattice structures. Most spectacular here are observations of the superfluid-Mott-insulator quantum phase transition or the first two-component mixture of Fermionic atoms [22,23]. In the context with new theoretical possibilities, systems with ultracold degenerate quantum gases in optical lattices may help to reach precise understanding of basic mechanisms of different quantum phase transitions in systems of strongly correlated electrons.

***Envisaged achievements**:* The envisaged achievements are a decipher of some of the issues raised above, the discovery of new materials with novel phenomena at low temperatures and the detailed understanding of the low temperature metallic phases via a close co-operation between experimental and theoretical groups. We aim to gain new knowledge on novel ground states, draw conclusions and achieve common agreement about

- origin and characteristics of unconventional SC phases near a QCP;
- microscopic models explaining the NFL behaviour and their spin charge and orbital fluctuation spectra;
- dimension dependence and characteristics of magnetic correlations;
- the single ion or coherent Kondo lattice type interaction responsible for NFL in HF systems;
- similarities and dissimilarities of scaling of the dynamical susceptibility for (ordinary and quadrupolar) Kondo systems;
- whether T_K stays finite when T_N vanishes or whether T_K and T_N vanish at the same point near the QPT?
- the role of metamagnetic criticality on NFL behaviour, the effect of reduced dimensionality and degeneracy of the ground state on NFL,
- how the scaling exponent relates to the origin of NFL?
- how pressure, composition and fields tune a system across the QCP and whether differences occur here in critical fluctuations,
- whether quantum phase transitions are continuous or discontinuous and role of nanoscale heterogeneities near these transitions,
- the emergence of unconventional forms of charge, current or spin order, such as orbital antiferromagnetism and toroidal magnetism, magnetism of singlet ground state systems.
- phase diagram of fermionic and/or bosonic atoms in optical lattices, regular or random, with single-band or with multi-band structure to achieve a better understanding of the physics of Hubbard models, Kondo systems, quantum spin glasses, and, more generally, of quantum phase transitions in strongly correlated systems.

REFERENCES

[1] D. Pines and P. Nozieres, *The Theory of Quantum Liquids*, Vol.1, Normal Fermi-liquid, Addison-Wesley, MA 1987.
[2] See for example, G.R. Stewart, Rev. Mod. Phys., 73, 797 (2001).
[3] D. Giuliano, B. Jouault and T. Tagliacozzo, Eur. Phys. Lett., 58, 401 (2002).
[4] S. Horiuchi, Y. Okimoto, R. Kumai and Y. Tokura, Science, 299, 229 (2003).
[5] S. Sachdev, *Quantum Phase Transtions*, Cambridge Univ. Press, Cambridge (1999).
[6] H. v. Löhneysen, J. Magn. Magn. Mat. 200, 532 (1999).
[7] A. J. Millis, Phys. Rev. B 48 7183 (1993).
[8] P. Coleman et al., J. Phys: Cond. Mat. 13 R 723 (2001).
[9] Q. Si et al., Nature 413 804 (2002).
[10] C.M. Varma, P.D. Littelwood, S. Schmittink, E. Abrahams, A.E. Ruckenstain, Phys. Rev. Lett., 63, 1996 (1989).
[11] M. Aronson et al, Phys. Rev. Lett. 75, 725 (1995).
[12] A. Schröder et al., Phys. Rev. Lett. 80, 5623 (1998); A. Schröder et al., Nature, 351 (2000).
[13] J.G. Park, et al., J. Phys. Cond. Matter, 14, 3865 (2002).
[14] N. D. Mathur et al, Nature, 394, 39 (1998).
[15] S.S. Saxena et al, Nature, 406, 587 (2000).
[16] V.A. Sidorov et al, Phys. Rev. Lett. 89, 157004, (2002); C. Petrovic et al, Euro Phys. Lett. 53, 354 (2001).
[17] E. Bauer et al., Phys. Rev. Lett. 92, 027003 (2004).

[18] T. Akazawa et al., J. Phys.: Cond. Mat. 16 L29 (2004).
[19] M. Matsumoto, Phys. Rev. B 68, 180403 (2003).
[20] D.A. McKeown et al., Phys. Rev. B 56, 3114 (1997).
[21] T. Rice, Science 298, 760 (2002).
[22] M. Greiner et al., Nature 415, 51 (2002).
[23] G. Modugno et al., Phys. Rev. A 68, 011601(R) (2003).

D. ORGANISATION

Management committee:
A management committee will be installed and will have the responsibilities of the actions taken. The management committee will meet, at least, once a year. Decisions will also be made by circulating documents, by e-mail and other electronic communication services. The MC will set-up and update regularly the website, which will consist of a precise description of each group, the available experimental equipment and availability, as well as computing capacities. Each participating group is obliged to provide appropriate information to the MC.

Activities:
Working groups meetings among the various groups will be held annually. Main emphasis will be laid to short term fellowships primarily awarded to younger researchers. One larger and one or two smaller scale workshops (conferences) will be held annually during the COST-Action period. Substantial participation on regular international conferences, such as the "International Conference on Strongly Correlated Electron Systems, SCES", "The International Conference on Magnetism, ICM" or the "International Conference on low Temperature Physics, LT" is foreseen.

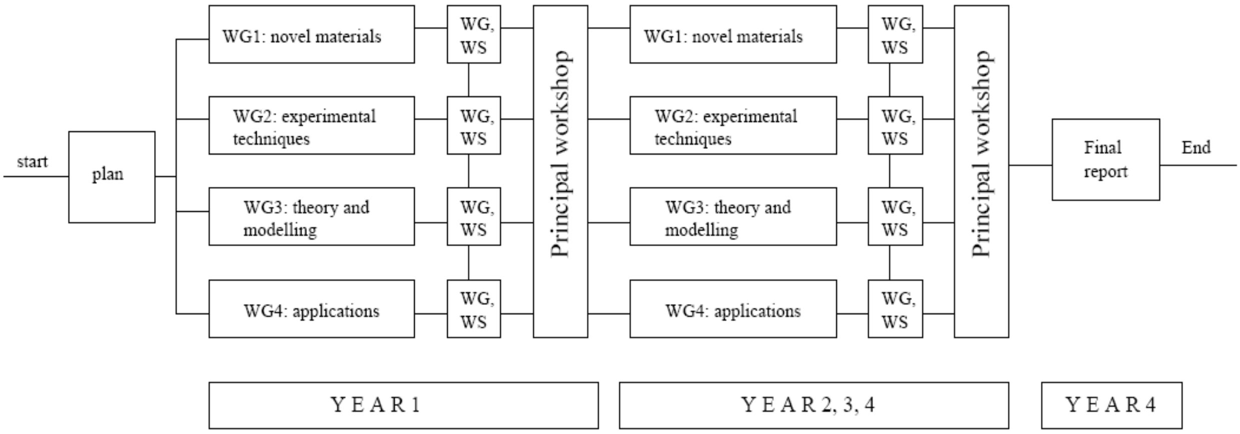
Working group meetings:
The working group meetings should comprise an appropriate number of scientists of a specific working group as well as additional researchers from complementary groups (e.g., experiments and theory).

Micro-workshops and short term scientific missions:
The exchange of ideas in small groups discussing a well defined issue is planned in terms of micro-workshops. The primary instrument within the Action, if accepted, will be short term scientific missions, STSM. This instrument allows younger researchers to improve skills and competence from research stays in partner laboraties, to transfer know-how by such visits and to solve specific scientific problems by methods and procedures available within the partner institutions of the proposed COST action.

E. TIMETABLE

The total duration of the Action is four years (2005-2008).

Each year about 5-7 working group meetings, up to 20 short-term scientific missions shall be supported as well as one large and one or two smaller workshops during the COST-Action period. The following scheme shows the structure of the proposed action.



F. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest:

Austria, Belgium, Croatia, France, Germany, Hungary, Italy, Poland, Russia, Slovakia, Slovenia, Spain, Switzerland, The Czech Republic, The Netherlands, United Kingdom.

An estimate of the total amount of research money spent on ECOM related projects is about EUR 4.200.000.-- per year. This number is based on the assumption that each of the about 30 different groups in 15 European countries involves about 4 researchers at least on a half-time base (with EUR 30.000 salary) although these researchers are not paid by COST, plus about EUR 5.000 of consumables and investments per researcher and year. The total number for the time of the COST action (four years) is then EUR 16.800.000. Additionally, beamtime at large facilities such as ISIS or ILL (assuming 200 to 400 instrument- beamdays per year) would add another 2 to 4 Mio Euro per year if 10,000,-- Euro per instrument-beam day is assumed.

On the basis of national estimates provided by the representatives of these countries, the economic dimension of the activities to be carried out under the Action has been estimated, in 2003 prices, at roughly Euro 95.000 per year, in total (2005-2008) about EUR 380.000.

This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

BUDGET ESTIMATE (numbers in EURO per year)

Workshops/Conferences:	75.000
Short time visits:	40.000
Working group meetings:	45.000
External administrative costs:	10.000
Committee meetings:	10.000
Sum:	180.000

Justification:

- *<u>Euro 50.000 to organise the annual principal workshop:</u>* Because of the timeliness and the importance of the field we plan to have an Annual

Conference on progress in the field of *Emergent Behaviour of Correlated Matter.* We would also like to have overseas participants (USA, Canada, Japan).

- *Euro 25.000 for 2 smaller scale workshops for meetings of the working parties:* These are related to specific topics within the programme, such as experiments under extreme conditions (magnetic fields, high pressure, very low temperatures, etc.), neutron -, μSR - , synchrotron experiments for solving specific problems.
- *Euro 40.000 for up to 20 short time scientific mission for young researchers:* These fellowships will constitute an essential part of the programme, serving two purposes: i) improve the skills of young researchers and, ii) foster exchange of experimental techniques and theoretical interpretations
- *Euro 45.000 for working group meetings:* These meetings will be necessary to co-ordinate sample preparation and exchange, measuring techniques, discussion of relevant models, discussion and final treatment of results.
- *Euro 5000 for publications:* We anticipate to publish a larger number of publications per year. Some of the most prestigious journals impose page charges, in addition, reprint charges have to be paid for practically all journals.
- *Euro 10.000 for administrative costs:* Establishing and maintaining the homepage of the proposed action; copies and other local expenses.
- *Euro 10.000 for committee meeting:* In order to manage the COST – action, the management will meet once a year.

G. DISSEMINATION PLAN

Dissemination of the results of the Action is specifically targeted to the contributing members of the COST-Action as well as to other researchers in the field, other research frameworks and Institutes and Academia and, if appropriate, industrial companies.

In order to provide these information, standard publication in well established peer-reviewed journals, at national and international conferences and symposia. Electronic possibilities such as web-sites and web-based data bases as well as an electronically distributed newsletter is envisaged. The website will be constituted by a "confidential" part, where partners at the COST action can exchange their results and a public part, where relevant results will be available for a general audience, presented in a popular manner.

Further channels of dissemination of knowledge are associated with the mobility of young researchers (due to a larger number of short time scientific mission) and workshops at different scales.

Additional Information:

The majority of participants of the present research proposal have been involved in a previous programme funded by the ESF entitled "Fermi liquid instabilities of correlated metals, FERLIN", which successfully was carried out from 1998 to 2003. This programme, which assisted the co-operation of scientists from 8 different European countries, is considered as one of the foremost reasons that European researchers are leading in the field of quantum phenomena in solids at low temperatures. Because of the expanding field concerning materials as well as various phenomena and the growing importance as one major aspect of the physics of condensed matter, a common structured continuation of research is strongly needed.

Expected benefit from European collaboration in this area:

The proposed programme intends to further improve understanding of materials with electronic correlations at low temperatures, which are expected to possess significant prospects for technical applications including devices and sensors, SC components or cooling modules based on the giant thermoelectric effects of strongly correlated electron systems. It additionally helps to integrate scientists from Eastern European countries, enabling extensive transfer of expertise, competence and skills to the formerly underfavoured regions. The programme contains, as a major component, education and training of European graduate - and post doctoral students. Synergetic effects are expected, since scientists from many different fields co-operate in the proposed programme. The research groups combine their various assets in different techniques in order to synergetically resolve the issues raised above. Requirements for measurements foreseen in the proposed project frequently push instrumentation towards its limits; such border cases will favour major experimental breakthroughs in the different experimental techniques notably with respect to extreme conditions (high pressure, very low temperatures or high magnetic fields), which may have important impact on other domains of physics (e.g., geophysics, astrophysics …) as well. Moreover, the planned co-operation is expected to favour an optimal use of large European facilities like those for neutron scattering, synchrotron radiation or high magnetic fields.

The expertise of the groups participating and the assignment of the different problems are summarised in the following table

Material synthesis	Amsterdam, Augsburg, Bordeaux, Cambridge, Dresden, Geneve, Grenoble, Karlsruhe, Leiden, Leuven, Prague, Santander, St. Andrews, Wien, Wroclaw,
Thermodynamic properties (specific heat, thermal expansion, magnetisation, de Haas van Alphen)	Amsterdam, Augsburg, Bordeaux, Braunschweig, Cambridge, Dresden, Geneve, Grenoble, Karlsruhe, Leuven, London, Prague, Santander, Southampton, St. Andrews, Wien, Wroclaw
Transport phenomena	Augsburg, Cambridge, Dresden, Geneve, Grenoble, Karlsruhe, Leuven, London, Prague, Santander, Southampton, St. Andrews, Wien, Wroclaw
Pressure studies and high magnetic fields	Amsterdam, Cambridge, Cologne, Braunschweig, Grenoble, Karlsruhe, Leiden, Leuven, Prague, PSI Villigen, ISIS Didcot, ILL Grenoble, St. Andrews, Wien
Neutron scattering	ILL Grenoble, PSI Villigen, ISIS Didcot, Moscow, CEA Saclay
Muon spin rotation (µSR)	PSI Villigen, ISIS Didcot
Scanning tunnelling microscopy and spectroscopy (at low temperatures and high magnetic fields), **NMR, NQR, Mössbauer spectroscopy**	Cologne, Dresden, Kosice, Madrid
Theory	Budapest, Cambridge, Krakow, Lubljana, Paris, Salerno, Zürich, Zagreb, Cologne, Karlsruhe, St. Andrews.

The applicants Co-ordinates and Curriculum Vitae

CURRICULUM VITAE: **Prof. Dr. Ernst BAUER**

Institute of Solid State Physics, Vienna University of Technology, Wiedner Hauptstraße 8-10, A-1040 Wien, Austria,Tel: +43 1 58 801 131 60, Fax: +43 1 58 801 131 99, e-mail: bauer@ifp.tuwien.ac.at

Date of birth: April 27, 1955, **Marital Status**: married (two children)
Address: Institut für Festkörperphysik, Vienna University of Technology, Wiedner Hauptstraße 8 –10, A-1040 Wien, Austria
Education: 1981: Diploma in Technical Physics, Vienna University of Technology 1984: Doctor of Technical Sciences, 1991: Venia Legendi (professorial dissertation) at the Vienna University of Technology a, subject: "Solid State Physics".
Position: since 1981- Assistant at the Institute for Experimental Physics, Technical University Vienna, Austria, since 1991 - Univ. Dozent, Assistant Professor, since October 1, 1997 – extraordinary Professor.
Research Activities and Results: Highly correlated electron systems, spin fluctuation systems, rare earth intermetallic compounds and materials for thermoelectric applications. Development of high pressure -, high field - and low temperature equipment. Leader of 6 research projects of the Austrian Science foundation, 1 NEDO project. Austrian member of the ESF Project FERLIN. About 230 papers in international journals and contributions to international conferences.

Recent relevant publications:

1.) E. Bauer et al., "Heavy fermion superconductivity and magnetic order in non-centrosymmetric $CePt_3Si$", Phys. Rev. Lett. 92 (2004) 027003;
2.) M. Yogi, Y. Kitaoka, S. Hashimoto, T. Yasuda, R. Settai, T. D. Matsuda, Y. Haga, Y. Onuki, P. Rogl, and E. Bauer, "Evidence for a Novel State of Superconductivity in Noncentrosymmetric CePt3Si: A 195Pt-NMR Study" Phys. Rev. Lett. 93 (2004) 027003;
3.) S.Gabani, E. Bauer et al., "Pressure induced quantum critical point and non-Fermi-liquid behaviour in hexaboride SmB_6", Phys. Rev. B 67 (2003) 172406;
4.) H. Michor, E. Bauer, et al., "Crystal Structure and Kondo Lattice Behaviour of $CeNi_9Si_4$", Phys. Rev. B 67 (2003) 224428.
5.) E. Bauer et al., "Crystal field effects and thermoelectric properties of $PrFe_4Sb_{12}$ skutterudite", Phys. Rev. B66, 214421 (2002);

CURRICULUM VITAE: **Prof. Dr. Hilbert von Löhneysen**

Physikalisches Institut, University of Karlsruhe, D-76128 Karlsruhe, Germany, Tel: +49-721-6083450, Fax: +49-721-6086103, e-mail: H.vL@phys.uni-karlsruhe.de

Date of birth: October, 25th 1946
Education: Diplom: October 1970, Universität Göttingen; PhD: June 1976, with Prof. Dr. D. Wohlleben, Universität zu Köln; Assistant: June 1976 – April 1977, Universität zu Köln; Postdoc: May 1977 – April 1978, CNRS, Centre de Recherches sur les Tres Basses Temperatures, Grenoble (Frankreich), Assistant: May 1978 – September 1981, RWTH Aachen; Privatdozent (Lecturer): October 1981 – March 1986, RWTH Aachen Professorship: April 1986 – present, Universität Karlsruhe (TH), professor of physics (C4); Director of the Institute for Solid State Physics, Forschungszentrum Karlsruhe Since July 2000;
Research Activities and Honors:
Physics of metallic nanostructures, properties of strongly correlated electron systems (HF materials), magnetism and superconductivity, metal-insulator transitions, thin films and multilayers;
Spokesman of SFB 195 "Lokalisierung von Elektronen in makroskopischen und mikroskopischen Systemen" at the Universität Karlsruhe (TH), January 1992 – September 1998; Chairman of the ESF research program "Fermi-liquid instabilities in correlated metal" (FERLIN), 1998 – 2003; 1983: Heinz-Maier-Leibnitz-Preis des BMBW

Recent relevant publications:

1.) F. Laube, G. Goll, H. v. Löhneysen, M. Fogelström, F. Lichtenberg, Spin-triplet superconductivity in Sr_2RuO_4 probed by Andreev reflection, Phys. Rev. Lett. 84, 1595 (2000)
2.) A.Schröder, G. Aeppli, R. Coldea, M. Adams, O. Stockert H. v. Löhneysen, E. Bucher, R. Ramasashvili, and P. Coleman, Onset of antiferromagnetism in heavy fermion metals, Nature 407, 351 (2000)

3.) C. Pfleiderer, M. Uhlarz, S. M. Hayden, R. Vollmer, H. v. Löhneysen, N. R. Bernhoeft, G. G. Lonzarich, Coexistence of superconductivity and ferromagnetism in the d-band metal $ZrZn_2$, Nature 412, 58 (2001)
4.) R. Vollmer, A. Faißt, C. Pfleiderer, H. v. Löhneysen, E. D. Bauer, P.-C. Ho, V. Zapf, M. B. Maple, Low-temperature specific heat of the heavy fermion superconductor $PrOs_4Sb_{12}$, Phys. Rev. Lett. 90, 057001 (2003)
5.) C. Pfleiderer, D. Reznik, L. Pintschovius, H. v. Löhneysen, M. Garst, A. Rosch, Partial order in the non-Fermi-liquid phase of MnSi, Nature, 427, 227 (2004).

CURRICULUM VITAE**: : Prof. Dr. Manfred SIGRIST**

Institute for Theoretical Physics, ETH-Honggerberg, 8093 Zurich, Switzerland, Tel.: +41-1-633-2584, Fax.: +41-1-633-1115, e-mail: sigrist@itp.phys.ethz.ch

Date of birth: December 31, 1960, **Marital Status**: married (one son)
Address: Institute for Theoretical Physics, ETH Zürich, ETH-Honggerberg CH-8093 Zurich, Switzerland
Education: 1980-1986: Education at ETH Zürich;Diploma in theoretical physics, 1986-1989: Doctor course in the Institut für Theoretische Physik of the ETH Zürich, Supervisor: Prof. T.M. Rice; 1989-1991: Post-Doc and foreign professor at the University of Tsukuba, Japan, with Prof. K. Ueda, 1991-1993: Post-Doc at the Paul Scherrer Institute (PSI) and at the ETH Zürich (Institut für Theoretische Physik) with Prof. T.M. Rice and Prof. K. Ueda, 1993-1995: Post-Doc at the Massachusetts Institute of Technology in Cambridge (Department of Physics), USA, with Prof. P.A. Lee, 1995 - 1997: Research-Fellow of Swiss National Fonds (PROFIL) at ETH in Zürich, 1997 - 2001: Professor at the Yukawa Institute for Theoretical Physics of the Kyoto University, Japan, since April 2001: Professor for Theoretical Physics at ETH Zürich
Research Activities and Honors: phenomenology of unconventional superconductivity in strongly correlated electron systems; low-energy properties of the periodic Anderson and Kondo lattice model in connection with the physics of HF materials; properties of low-dimensional cuprate systems: magnetism and superconductivity; thermodynamic properties of spin systems; magnetic and transport properties of nanocarbon systems.
PROFIL Fellowship from Swiss National Fonds in 1995; JPS Research Article Prize, 1996, of the Physical Society of Japan, for the article Paramagnetic Effect in High Tc Superconductors - A Hint for d-Wave Superconductivity together with T.M. Rice;
Latsis Prize of ETH Zürich, 1997, of the Fondation Latsis International in Geneva, Switzerland; for the work on strongly correlated electron systems, in particular, on unconventional superconductivity; Member of Editorial Board: Progress of Theoretical Physics, 1998 - ; Member of Editorial Board: Journal of Physical Society of Japan, 2000 - ; Member of Board of Reviewing Editors: Science 2000 - 2002 ; Award of Merit 2000, by the Society for Non-Traditional Technology, Tokyo, Japan for the research on Unconventional superconductivity in non-cuprate transition metal oxide systems; Member of Editorial Board: European Journal of Physics B 2002 - . Member of Advisory Editorial Board: Journal of Physics: Condensed Matter (IOP) 2002 - .

Recent relevant publications:
1.) B. Normand, T.M. Rice and M. Sigrist, M. Matsumoto, “Magnon dispersion in the field-induced magnetically ordered phase of $TlCuCl_3$“, Phys. Rev. Lett. 89, 077203 (2002).
2.) P.A. Frigeri, D.F. Agterberg, A. Koga and M. Sigrist, “Superconductivity without inversion symmetry: MnSi versus $CePt_3Si$”, Phys. Rev. Lett. 92, 097001 (2004).
3.) Y. Maeno, T.M. Rice and M. Sigrist, “The intriguing superconductivity of strontium ruthenate”, Physics Today, January 2001, 42 (2001).
4.) A. Furusaki, M. Matsumoto and M. Sigrist, “Spontaneous Hall effect in chiral p-wave superconductors”, Phys. Rev. B 64, 054514 (2001).
5.) H. Tsunetsugu, M. Sigrist and K. Ueda, “The ground state phase diagram of the one-dimensional Kondo lattice model”, Rev. Mod. Phys. 69, 809 (1997)

Management Committee

The proposed COST action intends to affiliate at least one scientist of each participating country. The following persons have agreed to participate in the MC:

AUSTRIA: E. Bauer, Institute of Solid State Physics, Vienna University of Technology
BELGIUM: V.V. Moshchalkov, Institute of Solid State Physics and Magnetism, KU Leuven,
CROATIA: V. Zlatic, Institute of Physics Zagreb
CZECH REPUBLIC: V. Sechovsky, Department of Electronic Structures, Charles University Prague
FRANCE: B. Coqblin, Laboratoire de Physique des Solides Université Paris-Sud, Prof. J. Flouquet, Commissariat à l'Energie Atomique (CEA) Grenoble .
GERMANY: H. von Löhneysen, Physikalisches Institut, University of Karlsruhe ; F. Steglich, Max Planck Institute for Chemical Physics of Solids
HUNGARY: P. Fazekas, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences
ITALY: F. Illuminati, Dipartimento di Fisica, Universita` di Salerno
POLAND: D.Kaczorowski, W. Trzebiatowski Institute of Low Temperature and Structure Research, Polish Academy of Sciences
SLOVAKIA: M. Reiffers, Institute of Experimental Physics, Slovak Academy of Sciences
SLOVENIA: P. Prelovsek, Institute J. Stefan, Ljubljana
SPAIN: J. Gomez-Sal, Departamento de Fisica de la Materia Condensada University of Cantabria, Santander
SWITZERLAND: M. Sigrist, Institute for Theoretical Physics, ETH Zürich,
The NETHERLANDS: A. deVisser, Van der Waals-Zeeman Institute for Experimental Physics, University of Amsterdam
UNITED KINGDOM: G. Lonzarich, Low Temperature Physics Group, Cavendish Laboratory, University of Cambridge

Programme Collaboration (*with relevant activities*)

The following list gives an overview on groups participating in the proposed action. Each of the groups consists of a number of researchers, actively working in the field of correlated electron systems. As an average, four scientists per group are assumed.

Austria:

Principal researcher: **Prof. E. Bauer,** Institute of Solid State Physics, Vienna University of Technology, Wiedner Hauptstraße 8-10, A-1040 Wien, Austria,Tel: +43 1 58 801 131 60, Fax: +43 1 58 801 131 99, e-mail: bauer@ifp.tuwien.ac.at

Study of unconventional SC in $CePt_3Si$ and related compounds; SC order parameter of systems without inversion symmetry; crystal growth and material characterization of new Yb-based compounds to investigate in comparison with Ce compounds the 4f electron-hole symmetry; synthesis of rare-earth intercalated graphite to study the influence of their quasi two-dimensional structure on their electronic and magnetic properties

Recent relevant publications:

1.) E. Bauer et al., “Heavy fermion superconductivity and magnetic order in non-centrosymmetric $CePt_3Si$“, Phys. Rev. Lett. 92 (2004) 027003;
2.) M. Yogi, Y. Kitaoka, S. Hashimoto, T. Yasuda, R. Settai, T. D. Matsuda, Y. Haga, Y. Onuki, P. Rogl, and E. Bauer, “Evidence for a Novel State of Superconductivity in Noncentrosymmetric CePt3Si: A 195Pt-NMR Study” Phys. Rev. Lett. 93 (2004) 027003;

3.) S.Gabani, E. Bauer et al., "Pressure induced quantum critical point and non-Fermi-liquid behaviour in hexaboride SmB_6", Phys. Rev. B 67 (2003) 172406;

Principal researcher: **Prof. P. Rogl**, Institute of Physical Chemistry, University Vienna, Währinger Straße 42, A-1090 Wien, Tel +43 1 4277 52456, Fax: +43 1 4277 9524, e-mail: peter.franz.rogl@univie.ac.at

Synthesis and structural characterisation of $CePt_3Si$ based derivative compounds; search for and investigations of new intercalated rare earth boron carbides; structural – chemical investigations to elucidate details of compound formation and compound stability; details on crystal structure, particularly precise atom site distribution; non-stoichiometry – defect structures.

Recent relevant publications: (see also E. Bauer)

1.) P. Rogl, "Phase Diagrams of Ternary Metal-Boron-Carbon Systems", Ed. G. Effenberg, ASM-MSIT; Materials Park, USA, pp. 1-566 (1998)

2.) P. Rogl and F. Bouree; "A Novel Boroncarbide, $Y_2B_3C_2$; X-ray Single Crystal and Neutron Powder Diffraction Analysis"; J. Alloys Compounds, 298, 160-163 (2000)

3.) T. Mori, T. Tanaka, P. Rogl, "Crystal Structure and Properties of Novel Quaternary Actinoid Boron Carbides $U_2ScB_6C_3$ and $Th_2ScB_6C_3$", J. Nucl. Sci. Technology, Suppl. **3**, 122-125 (2002)

Belgium:

Principal researcher: **Prof. Victor V. Moshchalkov,** Institute of Solid State Physics and Magnetism, KULeuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium, Tel: +32-16-327618
Fax: +32-16-327983, e-mail: victor.moshchalkov@fys.kuleuven.ac.be

Preparation and high field studies of nanostructured materials (exotic superconductors and magnetically doped semiconductors); structure of Landau levels in high magnetic fields; interplay between confinement imposed by boundaries of nanocells and magnetic confinement in semiconductors and metallic nanostructures of different shapes (quantum dots, rings, donuts, wires).

Croatia:

Principal researcher: **Prof. V. Zlatic,** Institute of Physics, Bijenicka c. 46, P.O.B. 304, 10 000 Zagreb, Croatia, Tel: +385-1-469-8815, Fax: +385-1-469-8889 , e-mail: zlatic@ifs.hr

Studies of new materials for correlated thermoelectrics and spintronic devices; theoretical modelling using several simplified generic models (Hubbard -, Anderson - or Falicov-Kimball model); development of novel non-perturbative approaches.

Recent relevant publications:

1.) J. K. Freericks and V. Zlatic, Exact solution of the Falicov-Kimball model\\ with dynamical mean-field theory, Review of Modern Physics, Vol. 75, p. 1333 (2003);

2.) V. Zlatic, I. Milat, B. Coqblin, G. Czycholl and C. Grenzbach, Thermoelectric power of Cerium and Ytterbium intermetallics, Physical Review, Vol. B68, p. 104432 (2003);

3.) J. K. Freericks, D. O. Demchenko, A. V. Joura, and V. Zlatic, Optimizing thermal transport in the Falicov-Kimball model, Physical Review B, Vol. 68, p. 195120 (2003).

Czech Republic:

Principal researcher: **Prof. V. Sechovsky,** Department of Electronic Structures, Charles University Prague, Ke Karlovu 5, 121 16 Praha 2, The Czech Republic; Tel: +420 2 21 91 13 67, Fax: +420 2 21 91 16 17 e-mail: sech@mag.mff.cuni.cz

Synthesis and single-crystal growth of novel Ce and U intermetallics, experimental and theoretical studies of thermodynamic, electrical and thermal transport properties, and microscopic mechanisms by neutron and synchrotron-

light scattering, μSR and positron annihilation. The microscopic experiments and studies of transuranium materials will be realized in collaboration with outside facilities (ILL, BENSC, ESRF, ANKA, PSI, Principal targets: exploring the field of unstable exotic magnetism, coexistence of superconductivity and magnetism in the novel strongly correlated 4f- and 5f-electron materials and understanding the relevant responsible mechanisms.

Recent relevant publications:

1.) S. Heathman, M. Idiri, J. Rebizant, P. Boulet, P.S. Normile, L. Havela, V. Sechovsky, T. Le Bihan, “UPd3 under high pressure: Lattice properties”, Phys. Rev. B 67 (2003) Art. No. 180101.

2.) K. Prokes, H. Nakotte, M.I. Bartashevich, M. Doerr, V. Sechovsky, “Neutron diffraction and magnetization studies of U2Pd2In single crystals in high magnetic fields”, Phys. Rev. B 68 (2003) Art. No. 014405.

3.) B. Janousova, J. Kulda, M. Divis, V. Sechovsky, T. Komatsubara, “Local symmetry of the crystal-field Hamiltonian of CePtSn by polarized neutron scattering , Phys. Rev. B 69 (2004) Art. No. 220412”.

France:

Principal researcher: **Directeur de Recherche CNRS. B. Chevalier,** ICMCB, Avenue du Dr. A. Schweitzer
F-33608 Pessac (France), Tel. +33 (0) 5 40 00 63 36, Fax. + 33 (0) 5 40 00 27 61
e-mail chevalie@icmcb.u-bordeaux1.fr

Influence of hydrogenation on the structural and physical properties of ternary compounds based on cerium. Study of transition intermediate valence state → magnetic ordering induced by hydrogen insertion (for instance in CeNiSn, CeNiIn,..).

Recent relevant publications:

1.) B. Chevalier, J.-L. Bobet, M. Pasturel, E. Bauer, F. Weill, R. Decourt and J. Etourneau. "Ferromagnetic behavior of the new hydride CeNiSnH1.8(2)". Chemistry of Materials, 15 (2003) 2181.

2.) B. Chevalier, M. Pasturel, J.-L. Bobet, J. Etourneau, O. Isnard, J. Sanchez Marcos, J. Rodriguez Fernandez. "Magnetic ordering induced by the hydrogenation of the ternary stannide CeNiSn". J. Magn. Magn. Mat., 272-276 (2004) 576.

3.) B. Chevalier and S. F. Matar. "Hydrogen insertion effect on the magnetic properties of CeCoSi". Phys. Rev. B, (to be published)

Principal researcher: **Prof. B. Coqblin,** Laboratoire de Physique des Solides, Bât. 510, Centre d'Orsay, Université Paris-Sud
91405 - Orsay - Cedex, France, Tel : +33-01 69 15 60 94, Fax : +33-01 69 15 60 86
e-mail: coqblin@lps.u-psud.fr

Theoretical investigations of the Kondo lattice problem (normal or "underscreened" Kondo lattice); occurrence of SC at low temperatures in HF or magnetic systems near a QCP; transport properties (thermoelectric power, thermomagnetic effect or the Nernst effect) in HF systems.

Recent relevant publications:

1) Band filling effects on the Kondo-lattice properties, B. Coqblin, C. Lacroix, M. A. Gusmao and J. R. Iglesias, Phys. Rev. B, 67, 064417 (2003).

2) Thermoelectric power of Cerium and Ytterbium intermetallics, V. Zlatic, I. Milat, B. Horvatic, B. Coqblin, G. Czycholl and C. Grenzebach, Phys. Rev. B, 68, 104432 (2003).

3) Study of the Quantum Critical Point in the Spin Glass-Kondo Transition in Heavy Fermion Systems, Alba Theumann and B.Coqblin, Phys. Rev. B, 69, 214418 (2004).

Principal researcher: **Prof. J. Flouquet,** Commissariat à l'Energie Atomique (CEA) Grenoble 17 avenue des martyrs, 38054 Grenoble, France (in association with JP Brison CNRS Centre de recherche des trés basses températures) Tel +33438785423 Fax +33438785060 e-mail: flouquet@cea.fr

Synthesis of large single crystals; instrumentation at low temperature; magnetic or metal-insulator quantum transitions under pressures up to 200 kbar; frustrated magnetic systems; role of disorder at quantum critical points and in frustrated systems; molecular magnets; vortex matter with special emphasis on unconventional SC.

Recent relevant publications:

1.) A. Huxley et al, "Realignment of the flux lattice by a change in the symmetry of superconductivity in UPt3", Nature 406, 160 (2000);
2.) J. Flouquet et al., "Ferromagnetic superconductors", Physics World 15, 41 (2002);
3.) D. Aoki et a.,l "Coexistence of superconductivity and ferromagnetism in URhGe", Nature 413, 613 (2001)

Germany:

Principal researcher: **Prof. M. M. Abd-Elmeguid,** II. Physikalisches Institut, University of Cologne,
Zülpicherstraße 77, 50937 Köln, Tel: +49 221 470 2625, Fax: +49 221 470 5178, e-mail: meguid@ph2.uni-koeln.de

Measurements of Electrical and magnetical transport; Mössbauer spectroscopy and x-ray diffraction under very high pressures and at low temperatures. Study of quantum critical point in Yb-based HF systems and metal-insulator transitions in correlated oxides.

Recent relevant publications:

1.) M. M. Abd-Elmeguid, B. Ni, D. I. Khomskii, R. Pocha, D. Johrendt, X. Wang, and K. Syassen, "Transition from Mott insulator to superconductor in GaNb4Se8 and GaTa4Se8 under high pressure", Phys. Rev. Lett. 93, 126403 (2004).
2.) A. Barla, J. P. Sanchez, Y. Haga, G. Lapertot, B. P. Doyle, O. Leupold, R. Rüffer, M. M. Abd-Elmeguid, R. Lengsdorf, and J. Flouquet, "Pressure-Induced Magnetic Order in Golden SmS", Phys. Rev. Lett. 92, 066401 (2004).3.) J. Plessel, M.M. Abd-Elmeguid, J.P. Sanchez, G. Knebel, C. Geibel, O. Trovarelli, and F. Steglich, "Unusual behavior of the low moment magnetic ground state of YbRh2Si2 under high pressure", Phys. Rev. B 67, 180403(R) (2003).

Principal researcher: **Prof. A. Eichler,** University of Braunschweig, Institute of Technical Physics, Mendelssonstraße 2, D-38106 Braunschweig, Tel: +49 531 391 8502
Fax:+49 531 391 8511, e-mail: a.eichler@tu-bs.de

Specific heat and magnetic susceptibility studies at high pressure and low temperatures; development of high pressure equipment; development of novel measurement procedures.

1.) H. Neemann, A. Eichler, S. Süllow, J.A. Mydosh, "Search for a quantum critical point in CePd2Al2Ga by specific heat measurements under pressure", Acta Phys. Pol. B. 34 (2003) 1085.
2.) A.U.B. Wolter, H.-H. Klauss, F.J. Litterst, T. Burghardt, A. Eichler, R. Feyerherm, S. Süllow, "A pressure study of the antiferromagnetic phase of FePM2CL2 (PM = pyrimidine)", to be published.
3.) J. Larrea J., T. Burghardt, A. Eichler, M.B. Fontes, A.D. Alvarenga, E. Baggio-Saitovitch, "Quantum critical point in ferromagnetic Kondo lattice CePt at high pressure", J. Magn. Magn. Mater. 272 (2004) 52.

Principal researcher: **Prof. H. von Löhneysen,** Physikalisches Institut, University of Karlsruhe, D-76128 Karlsruhe, Germany, Tel: +49-721-6083450, Fax: +49-721-6086103, e-mail: H.vL@phys.uni-karlsruhe.de

Measurements of thermodynamic and transport properties in a wide temperature, pressure and magnetic field range; elastic and inelastic neutron scattering (in co-operation with CEA Saclay); study of quantum critical points in *particular in HF systems and transition-metal intermetallics and magnetic SC; molecular magnets.*

Recent relevant publications:

1.) A.Schröder, G. Aeppli, R. Coldea, M. Adams, O. Stockert H. v. Löhneysen, E. Bucher, R. Ramasashvili, and P. Coleman, Onset of antiferromagnetism in heavy fermion metals, Nature 407, 351 (2000)

2.) C. Pfleiderer, M. Uhlarz, S. M. Hayden, R. Vollmer, H. v. Löhneysen, N. R. Bernhoeft, G. G. Lonzarich, Coexistence of superconductivity and ferromagnetism in the d-band metal $ZrZn_2$, Nature 412, 58 (2001)

3.) C. Pfleiderer, D. Reznik, L. Pintschovius, H. v. Löhneysen, M. Garst, A. Rosch, Partial order in the non-Fermi-liquid phase of MnSi, Nature, 427, 227 (2004).

Principal researcher: **Prof. Dr. Achim Rosch,** Institut für Theoretische Physik, University of Cologne, Zülpicher Str.77, D-50937 Köln, Tel.: +49 (0)221 470 4994, Fax: +49 (0)221 470 2189, e-mail: rosch@thp.uni-koeln.de

Theory of heat-, charge- and spin transport in quasi one-dimensional systems; theory of quantum critical points in nearly magnetic metals (including transport properties), strongly correlated systems out of equilibrium

Recent relevant publications:

1.) Lijun Zhu, Markus Garst, Achim Rosch, Qimiao Si, Universally diverging Grüneisen parameter and magnetocaloric effect close to quantum critical points, Phys. Rev. Lett. 91, 066404 (2003).

2.) C. Pfleiderer, D. Reznik, L. Pintschovius, H. v. Löhneysen, M. Garst, A. Rosch, Partial order in the non-Fermi-liquid phase of MnSi, Nature, 427, 227 (2004).

3.) P. C. Howell, A. Rosch and P. J. Hirschfeld, Relaxation of Hot Quasiparticles in a d-Wave Superconductor, Phys. Rev. Lett. 92, 037003 (2004).

Principal researcher: **Dr E.W. Scheidt**, Institut für Physik, Lehrstuhl für Chemische Physik und Materialwissenschaften, Universität Augsburg, D-86135 Augsburg Tel: +49 0821 - 598 3356, Fax: + 49-821-598-3227, e-mail: ernst-wilhelm.scheidt@physik.uni-augsburg.de

Thermodynamic and transport properties in heavy fermions and organic and organometallic compounds; measurements of bulk properties over a wide temperature range down to 30 mK and in high magnetic fields up to 17 T; preparation and structural characterisation of single crystals.

Recent relevant publications:

1) U. Killer, E.-W. Scheidt, G. Eickerling, H. Michor, J. Sereni, Th. Pruschke and S. Kehrein, "Unusual Single-Ion Non-Fermi Liquid Behavior in Ce1-xLaxNi9G4, Phys. Rev. Lett. (2004), in print.

2.) R. Küchler, P. Gegenwart, K. Heuser, E.-W. Scheidt, G. R. Stewart and F. Steglich, "Grüneisen Ratio Divergence at the Quantum Critical Point in CeCu6-xAgx", Phys. Rev. Lett. (2004), 92, 27003, (2004)..

3.) E. Bauer, G. Hilscher, H. Michor, Ch. Paul, E.-W. Scheidt, A. Gribanov, Yu. Seropegin, H. Noël, M. Sigrist and P. Rogl, "Heavy fermion superconductivity and magnetic order in non-centrosymmetric CePt3Si", Phys. Rev. Lett. 92, 27003, (2004).

Principal researcher: **Prof. F. Steglich,** Max Planck Institute for Chemical Physics of Solids, Noethnitzer Str. 40, D-01187 Dresden, Germany, Tel: +49-351-46 46 39 00, Fax: +49-351-46 46 39 02, e-mail: steglich@cpfs.mpg.de

Search for and investigation of new Yb- and Eu-based HF compounds; synthesis and study of high quality $CeCu_2Si_2$ single crystals; measurement of various thermodynamic and transport properties partly under high pressure and high magnetic fields; neutron scattering; microscopic probes such as NMR, ESR, and a STM at low temperatures; anisotropic and nodal SC in HF metals and borocarbides; dual nature of 5f electrons in U-based HF metals.

Recent relevant publications:

1.) "Strong Electron Correlations in Magnetic Systems", F. Steglich, Europhysics News 34, 243 (2003).

2.) “Observation of two distinct superconducting phases in CeCu2Si2”, H. Q. Yuan, F. M. Grosche, M. Deppe, C. Geibel, G. Sparn and F. Steglich, Science 302, 2104 (2003).
3.) “The break-up of heavy electrons at a quantum critical point”, J. Custers, P. Gegenwart, H. Wilhelm, K. Neumaier, Y. Tokiwa, O. Trovarelli, C. Geibel, F. Steglich, C. Pépin and P. Coleman, Nature 424, 524 (2003).

Principal researcher: **Prof. Dr. Matthias Vojta,** Institut für Theorie der Kondensierten Materie, University Karlsruhe, Postfach 6980, D-76128 Karlsruhe, Germany Tel: +49 721 608-7005,
Fax: +49 721 608-7779, e-mail: vojta@tkm.physik.uni-karlsruhe.de

Theoretical investigation of competing orders, quantum critical phenomena, and non-Fermi liquid behavior in magnetic metals and doped Mott insulators; exotic phases in correlated systems; frustrated magnetism

Recent relevant publications:

1.) M. Vojta, T. Ulbricht, Magnetic excitations in a bond-centered stripe phase: Spin waves far from the semi-classical limit, Phys. Rev. Lett. (2004) to appear.
2.) T. Senthil, M. Vojta, S. Sachdev, Weak magnetism and non-Fermi liquids near heavy-fermion critical points, Phys. Rev. B 69, 035111 (2004).
3.) T. Senthil, S. Sachdev, M. Vojta, Fractionalized Fermi liquids, Phys. Rev. Lett. 90, 216403 (2003).

Hungary:

Principal researcher: **Prof. P. Fazekas,** , Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, 29-33 Konkoly-Thege M. Street, Budapest, Hungary; Tel: + 36 1 392 2222 /1913, Fax: +36 1 392 2218, e-mail: pf@szfki.hu

Theoretical studies on multipolar ordering in f-electron systems;, d-electron-based spin-orbital systems; studies of the electrical and magnetic properties and the phase diagram of $BaVS_3$ $LiNiO_2$*, and Bechgaard salts.*

Recent relevant publications:

1.) F. Vernay, K. Penc, P. Fazekas, and F. Mila: “Orbital degeneracy as a source of frustration in LiNiO2”, Physical Review B 70, 014428 (2004)
2.) A. Kiss and P. Fazekas: “Octupolar ordering of Γ_8 ions in magnetic field”, Physical Review B 69, 174425 (2003)
3.) A. Kiss and P. Fazekas, “Quadrupolar interactions in Pr compounds: PrFe4P12 and PrBa2Cu3O6”, Journal of Physics: Condensed Matter 15, S2109 (2003).
4.) L. Forró, R. Gaál, H. Berger, P. Fazekas, K. Penc, I. Kézsmárki, and G. Mihály, “Pressure induced quantum critical point and non-Fermi-liquid behavior in BaVS3” , Physical Review Letters 85, 1938 (2000).

***Italy*:**

Principal researcher: **Prof. F. Illuminati**, Dipartimento di Fisica, Universita` di Salerno, Via S. Allende, I-84081 Baronissi (SA) Italy, Tel: +39 089 965 287; Fax: +39 089 965 275; e-mail: illuminati@sa.infn.it

Study of the phase diagram of spin-polarized fermions in optical lattices: p-wave and d-wave pairings in antiferromagnetic configurations; study of Kondo systems for bosons and fermions in multi-band optical lattices and in doubly-periodic lattices; BCS-BEC crossover and induced superfluidity of fermionic atoms in lattice boson-fermion mixtures; simulations of quantum spin glass physics in random optical lattices.

Poland:

Principal researcher: **Prof. D. Kaczorowski**, W. Trzebiatowski Institute of Low Temperature and Structure Research Polish Academy of Sciences, ul. Okólna 2, PO Box 1410, 50-950 Wroclaw 2, Poland, Tel: +48-71-343 50 21, Fax: +48-71-344 10 29, e-mail: dkaczor@int.pan.wroc.pl

Anomalous phenomena in d- and f-electron systems; transport properties in strongly and moderately correlated spin systems; nonmagnetic Kondo effect in crystalline solids; structure of defects and appearance of nonmagnetic Kondo effect; inhomogeneous charge and spin ordering in strongly correlated electron systems; thermo-magnetic phenomena in SC; pinning effects in SC; phase fluctuations and pseudogap in high-Tc SC; future applications in artificially gate-voltage doped SC; physics in confined geometry

Recent relevant publications:

1.) D.Kaczorowski, Yu.Prots and Yu.Grin, "Superconductivity in $La_3Rh_2Ge_2$ and dense Kondo behavior in $Ce_3Rh_2Ge_2$", Phys. Rev. B 64 (2001) 224420.

2.) A.P.Pikul, D.Kaczorowski, T.Plackowski, A.Czopnik, H.Michor, E.Bauer, G.Hilscher, P.Rogl and Yu.Grin, "Kondo behavior in antiferromagnetic $CeNiGe_3$", Phys. Rev. B 67 (2003) 224417.

3.) T.K.Kopec and T.P.Polak, "Superconducting-insulating transition in quantum three-dimensional Josephson junction arrays with magnetic and charge frustration", Phys. Rev. B 67 (2003) 214505.

Principal researcher: **Prof. J. Spalek** Marian Smoluchowski Institute of Physics, Jagiellonian University,
ulica Reymonta 4, PL - 30 - 059 Krakow, Poland; Tel. +48 12 663 5685, Fax: +48 12 633 40 79, e-mail: ufspalek@if.uj.edu.pl

Theoretical studies of magnetic, orbital, and SC order in strongly correlated systems and their mixed phases; special emphasis is paid to meta-insulator transitions, Luttinger liquid behaviour (including nanoscopic systems, and both high-Tc and ferromagnetic SC, and to the extension of the studies of quantum critical phenomena to the orbitally degenerate systems.

Russia:

Principal researcher: ***Prof. P. A. Alekseev,*** Russian Research Centre "Kurchatov Institute", Kurchatov Square 1, Moscow 123182, Russia; Phone: +7-095-196-76-62, Fax: +7-095-196-59-73; e-mail: paval@isssph.kiae.ru

Detailed studies of lattice and magnetic dynamics in strongly correlated f-electron systems by neutron scattering (in co-operation with LLB, Saclay and ISIS, Didcot), structural X-ray investigations. Competition between hybridisation effects, crystal field splitting and exchange interaction for series of mixed valence systems based on Ce, Sm and Yb (SmB_6, SmS, YbB_{12}, RENi)

Recent relevant publications:

1.) P.A. Alekseev, J.-M. Mignot, K.S. Nemkovski, E.V. Nefeodova, N. Yu. Shitsevalova, Yu. B. Paderno, R.I. Bewley, R.S. Eccleston, E.S. Clementyev, V.N. Lazukov, I.P. Sadikov and N.N. Tiden, "Yb-Yb correlations and crystal-field effects in the Kondo insulator YbB12 and its solid solutions ", J. Phys.: Condens. Matter 16, 2631 (2004).

2.) E.V. Nefeodova, P.A. Alekseev, V.N. Lazukov, and I.P. Sadikov, "The thermodynamic properties and special features of spectra of elementary excitations of unstable valence Sm-and Ce-based compounds", JETP 96, 1113 (2003).

3.) P.A. Alekseev, J.-M. Mignot, A. Ochiai, E.V. Nefeodova, I.P. Sadikov, E.S. Clementyev, V.N. Lazukov, M. Braden and K.S. Nemkovski, "Collective magnetic excitations in mixed-valence $Sm_{0.83}Y_{0.17}S$", Phys. Rev. B 65 , 153201 (2002)

Slovakia:

Principal researcher: **Dr. M. Reiffers**, Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, SK-043 53 Kosice, Tel: +421-55-622 8158, Fax: +421-55-633 6292 e-mail: reiffers@saske.sk

Detailed studies of strongly correlated low carrier density systems (Kondo insulators, e.g., SmB_6) with transport and spin gaps; study dimension effects on physical properties of Kondo insulators; high resolution infrared photo-emission spectroscopy and point contact spectroscopy at low temperatures and high magnetic fields.

1.) M. Reiffers, S. Ilkovič, A. Zorkovská, and E. Bauer, „Point contact properties of non Fermi-liquid compound YbCu3.5Al1.5“, J. Magn. Mag. Mater. 272-276, P1 (2004) 625;
2.) M. Reiffers et al., „Electron-quasiparticle interaction in the melt-spun cubic RECu5 (RE – heavy rare earth)“, physica status solidi (a) 196,1 (2003) 286;
3.) K. Flachbart, K. Gloos, E. Konovalova, Y. Paderno, M. Reifers, P.Samuely, and P. Švec, „Energy gap of intermediate-valent SmB6 studied by point-contact spectroscopy“, Physical Review B64 (2001) 0851041-0851048

Slovenia:

Principal researcher: **Prof. P. Prelovsek,** Institute J. Stefan, P.O. Box 3000, SI-1001 Ljubljana, Tel: +386 1 477 3496, Fax: +386-1-251 9385, e-mail: peter.prelovsek@ijs.si

Development and application of advanced numerical methods to study dynamical properties of correlated electrons at finite temperatures, development of an extended dynamical mean-field theory, charge and spin dynamics as well as transport in doped semiconductors; theoretical study of the interplay between itinerant metallic behaviour and magnetism leading to anomalous electronic properties and NFL transport behaviour in doped antiferromagnets, high-Tc SC cuprates, and itinerant ferromagnets.

Recent relevant publications:

1.) J.Jaklič, P.Prelovšek, Finite-temperature properties of doped antiferromagnets, Adv. Phys. 49, 1 (2000)
2.) I.Sega, P.Prelovšek, and J.Bonča, Magnetic fluctuations and resonant peak in cuprates: Towards a microscopic theory, Phys. Rev. B 68, 054524 (2003)
3.) P.Prelovšek, I.Sega, and J.Bonča, Scaling of the Magnetic response in doped antiferromagnets, Phys. Rev. Lett. 92, 027002 (2004)

Spain:

Principal researcher: **Prof. J. Gomez-Sal,** Departamento de Fisica de la Materia Condensada
Facultad de Ciencias. Av.de los Castros. s/n. Universidad de Cantabria.39005. Santander, Tel: +34-942 201506, Fax: +34-942 201402, e-mail: gomezjc@unican.es

Synthesis and study of new Ce and Yb nanostructured materials; investigation of Ce based bulk materials and corresponding hydrides compounds
Synthesis and study (thermal, magnetic and transport properties) of new Ce and Yb nanostructured materials; Magnetic clusters and complex spin structures. Superconductivity in incipient antiferroagnets LaMnAg, investigation of Ce based bulk materials and corresponding hydrides compounds

Recent relevant publications:

1.) N.Marcano, G. .M.Kalvius, D.R.Noakes, J.C.Gómez Sal, R.Wappling, J.I.Espeso,. E.Schreier, A. Kratzer, Ch.Baines and A.Amato. “Local spin disorder in the magnetic Kondo compounds CeNi1-xCux”. .Physica Scripta, 68, 298-318, (2003)
2.) P. Gorria, D. Martínez-Blanco, J. A. Blanco, A. Hernando, J. S. Garitaonandia, L. Fernández Barquín, J. Campo and R. Smith. “Invar effect in fcc fe-cu solid solutions” Physical Review B 69, 21421 (2004).
3.) A.Señas, J. Rodríguez Fernández, J. C. Gómez Sal , J. Campo.and J.Rodríguez Carvajal. “From ferromagnetism to inconmensurate magnetis structures: aneutron diffraction study of the chemical substitution effects in TbPt1-xCux .” Physical Review. B to appears in 2004.

Principal researcher: **Prof F. Guinea,** ICMM, CSIC, Campus Cantoblanco, Madrid,
Phone: + 34 91 3349047, Fax + 34 91 3720 623, e-mail: Paco.guinea@icmm.csic.es

Study of the pairing interaction of unconventional SC, the local distribution of Josephson currents and the role of disorder in magnetically frustrated compounds or in materials near a quantum critical transition by scanning tunneling microscopy and spectroscopy (STM/S) with in-situ nanofabricated, SC tips at very low temperature under magnetic fields of up to 13 T

Switzerland:

Principal researcher: **Dr. A. Amato,** Laboratory for Muon-Spin Spectroscopy, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland, Phone: +41 56 310 3232, Fax: +41 56 310 3131 (3130), E-mail: alex.amato@psi.ch

Microscopic investigation by muon-spin-rotation (µSR) of strongly correlated systems near magnetic instabilities; detection of magnetic fluctuations in the formation of novel SC states; µSR under pressure up to 15 kbar.

Recent relevant publications:

1.) A. Kanigel, A. Keren, L. Patlagan, K. B. Chashka, P. King, and A. Amato, "Muon Spin Relaxation Measurements of Na_xCoO_2 yH_2O", Phys. Rev. Lett. 92, 257007 (2004).
2.) A. Kanigel, A. Keren, Y. Eckstein, A. Knizhnik, J.S. Lord and A. Amato, "Common Energy Scale for Magnetism and Superconductivity in Underdoped Cuprates: A Muon Spin Resonance Investigation of $(Ca_xLa_{1-x})(Ba_{1.75-x}La_{0.25+x})Cu_3O_y$, Phys. Rev. Lett. 88, 137003 (2002).
3.) A. Amato, M.J. Graf, A. de Visser, H. Amitsuka, D. Andreica and A. Schenck, "Weak magnetism phenomena in heavy-fermion superconductors: selected µSR studies", J. Phys.: Condensed Matter 16 (2004).

Principal researcher: **Prof. D. van der Marel:** DPMC, Université de Genève, 24 quai Ernest-Ansermet - 1211 Geneve 4, Switzerland, Tel. + 41 22 379 6234, Fax: + 41 22 379 6869, e-mail: Dirk.VanDerMarel@physics.unige.ch

Optical measurements to study quantum critical points and the breakdown of the FL near metal-insulator transitions in transition-metal oxides and superconductor-insulator transitions in ultraclean nanofilms; optical study of quantum spin systems; THz excitations of correlated FL; development of a high pressure infrared spectrometer.

Recent relevant publications:

1.) D. van der Marel, H. J. A. Molegraaf, J. Zaanen, Z. Nussinov, F. Carbone, A. Damascelli, H. Eisaki, M. Greven, P. H. Kes, & M. Li, “Quantum critical behaviour in a high-Tc superconductor”, Nature 425, 271-274 (2003)
2.) F. P. Mena, D. van der Marel, M. Faeth, A. A. Menovsky, J. A. Mydosh “Heavy Carriers and Non-Drude Optical Conductivity in MnSi”, Phys. Rev. B 67, R241101 (2003)
3.) H. J. A. Molegraaf, C. Presura, D. van der Marel, P. H. Kes, and M. Li, “Superconductivity Induced Transfer of In-Plane Spectral Weight in BiSr2CaCu2O8+d”, Science 295, 2239-2241 (2002).

Principal researcher: **Prof. M. Sigrist,** ETH Zürich, Institute for Theoretical Physics, ETH-Honggerberg
8093 Zurich, Switzerland, Tel.: +41-1-633-2584, Fax.: +41-1-633-1115, e-mail: sigrist@itp.phys.ethz.ch

Theoretical study of strongly correlated electron systems with special emphasis on unconventional superconductivity and magnetism; quantum phase transitions in Mott-insulating and itinerant systems of transition metal oxides and heavy Fermion systems. Numerical simulations.

Recent relevant publications:

1.) B. Normand, T.M. Rice and M. Sigrist, M. Matsumoto, “Magnon dispersion in the field-induced magnetically ordered phase of $TlCuCl_3$“, Phys. Rev. Lett. 89, 077203 (2002).
2.) P.A. Frigeri, D.F. Agterberg, A. Koga and M. Sigrist, “Superconductivity without inversion symmetry: MnSi versus $CePt_3Si$”, Phys. Rev. Lett. 92, 097001 (2004).
3.) H. Tsunetsugu, M. Sigrist and K. Ueda, “The ground state phase diagram of the one-dimensional Kondo lattice model”, Rev. Mod. Phys. 69, 809 (1997)

The Netherlands:

Principal researcher: **Dr. A. de Visser,** Van der Waals-Zeeman Institute for Experimental Physics, University of Amsterdam, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands,
Tel: +31 20 525 5732, Fax: +31 20 525 5788, e-mail: devisser@science.uva.nl

Studies of Ce- and U-systems; expertise for low-temperature dilatometry and heat capacity at high fields; single crystal growth and characterization; experiments in high magnetic fields up to 33 T via a collaboration with University of Nijmegen

Recent relevant publications:

1.) A. de Visser, M.J. Graf, P. Estrela, A. Amato, C. Baines, D. Andreica, F.N. Gygax and A. Schenck “Magnetic quantum critical point and superconductivity in UPt3 doped with Pd” Phys. Rev. Lett. 85 (2000) 3005.
2.) P. Estrela, A. de Visser, T. Naka, F.R. de Boer and L.C.J. Pereira, “High-pressure study of the non-Fermi liquid material U2Pt2In” , Eur. J. Phys. B 43 (2001) 449.
3.) M.J. Graf, A. de Visser, C.P. Opeil, J.C. Cooley, J.L. Smith, A. Amato, C. Baines, F. Gygax and A. Schenck, “Onset of antiferromagnetism in UPt3 via Th substitution: a muon spin spectroscopy study”, Phys. Rev. B 68 (2003) 224421.

Principal researcher: **Prof. J.A. Mydosh,** Kamerlingh Onnes Laboratory, Leiden University, 2300RA Leiden, The Netherlands, Tel: +31 71 5275467, Fax: +31 71 527 5404 e-mail: mydosh@phys.leidenuniv.nl

Investigations of uranium based materials exhibiting quantum magnetism, hidden order and unconventional superconductivity. Growth of single crystals and metallurgical characterizations. Experimental studies of thermodynamic and transport properties under high magnetic fields and pressures. International collaborations at large scale facilities employing neutron and synchrotron scattering and high pulsed and static magnetic fields. Particular emphasis devoted to the hidden order and creation of novel phases at the quantum critical (end) point of URu_2Si_2.

Recent relevant publications:

1.) N. Harrison, M. Jaime and J. A. Mydosh, "Re-entrant hidden order at a metamagnetic quantum critial end point". Phys.Rev.Lett. 90,096402(2003).
2.) K. H. Kim, N. Harrison, M. Jaime, G. S. Boebinger and J. A. Mydosh, "Magnetic-field-induced quantum critical point and competing order parameters in URu2Si2". Phys.Rev.Lett. 91,269902(2003).
3.) P. Chandra, P. Coleman, J. A. Mydosh and V. Tripathi, "Hidden orbital order in the heavy fermion metal URu2Si2", Nature 417,831(2002).

United Kingdom:

Principal researcher: **Dr. D. Adroja,** ISIS Facility, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0 QX, Tel: +44 1235 445797, Fax: +44 1235 445103, e-mail: D.T.Adroja@rl.ac.uk

Study of spin dynamics using neutron scattering and muon-spin relaxation study on well characterised stoichiometric systems; investigations of NFL behaviour in stoichiometry systems to omit the effect of disorder (e.g., $Ce_2Rh_3Ge_5$); NFL *behaviour near ferromagnetic-QPT; NFL behaviour due to quadrupolar Kondo effect; NFL behaviour at metamagnetic criticality; NFL in low dimensional systems. Understanding the charge and spin gap formation in heavy fermion systems and their role in the observed NFL at low temperatures in CeRhSn and CeRu4Sb12*

Recent relevant publications:

1.) D.T. Adroja, W. Kockelmann, A.D. Hillier, K.S. Knight and B.D. Rainford Reduced moment antiferromagnetic Kondo lattice: Ce8Pd24Ga", Phys. Rev. B67 134419 (2003)
2.) J -Y So, J-G Park, D T Adroja, K A McEwen, A P Murani and S-J Oh, "Understanding the origin of non-Fermi liquid behavior in doped Kondo insulators",J. PHYSICS-CONDENSED MATTER 15, S2153 (2003)
3.) D.T. Adroja, J.-G. Park, K.A. McEwen, N. Takeda, M. Ishikawa, J.Y. So, "Investigation of spin gap in heavy fermion Skuttrudite: CeRu4Sb12", Phys. Rev. B, 68, 094425 (2003)

Principal researcher: **Prof. G. Aeppli,** Department of Physics and Astronomy, University College London Gower Street London WC1E, Tel +44 (0)20 7679 3448, Fax +44 (0)20 7679 7145/1360 e-mail: lcn-director@ucl.ac.uk,

Electrical transport, bulk magnetometry, scan probe microscopy, neutron scattering, and Xray microscopy of strongly correlated Fermi systems. Fabrication, using a range of techniques including focused ion beams and e-beam lithography, and characterization of devices (e.g.based on Josephson effect and spin-dependent tunnelling) derived from materials containing strongly interacting Fermions.

Recent relevant publications:

1.) S. Ghosh et al., "Entangled quantum state of magnetic dipoles", Nature 425, 48 (2003);
2.) A. Yeh et al., "Quantum Phase Transition in a Common Metal", Nature 419, 459 (2002);
3.) B. Lake et al., "Antiferromagnetic Order Induced by an Applied Magnetic Field in a High-Temperature Superconductor", Nature 415, 299, (2002).

Principal researcher: **Prof. K. A. McEwen:** Department of Physics and Astronomy, University College London, Gower Street, London, WC1E 6BT, UK, Tel: +44 20 7679 3492, Fax: +44 20 7679 1360 e-mail: k.mcewen@ucl.ac.uk

Novel uranium and neptunium-based intermetallic compounds; quadrupolar and orbital ordering in 4f and 5f systems, dynamical susceptibility of non-Fermi liquid materials ; spin gaps in Kondo lattice systems; effects of reduced dimensionality on strongly correlated electron systems; principal experimental techniques – neutron spectroscopy and resonant x-ray scattering.

Recent relevant publications

1.). J-G. Park, D.T. Adroja, K.A. McEwen and A.P. Murani, Non-Fermi liquid behaviour in the dynamic susceptibility of Ce(Rh 0.8 Pd0.2)Sb, J.Phys: Cond. Matt. 14 (2002) 3865
2.) K.A. McEwen, J-G. Park, A.J. Gipson and G.A. Gehring, A new model for the crystal field and the quadrupolar phase transitions in UPd3, J. Phys: Cond. Matt, 15 (2003) S1923
3.) D.T. Adroja, J-G. Park, K.A. McEwen, N. Takeda, M. Ishikawa and J-Y. So, Investigations of the spin
gap formation in a heavy fermion skutterudite compound: CeRu4Sb12, Phys Rev B, 68 (2003) 094425
4.) D.F. McMorrow, K.A. McEwen, J-G. Park, S. Lee, D. Mannix, F. Iga, T. Takabatake, Coupling of lattice and spin degrees of freedom in GdB6, Physica B 345 (2004) 66

Principal researcher: **Prof. A. Mackenzie,** School of Physics & Astronomy University of St Andrews North Haugh St Andrews KY16 9SS Scotland, UK Tel: +01334 463108, Fax: (01334) 463104, e-mail: apm9@st-and.ac.uk

*Experimental study of quantum phases in ruthenates and other transition-metal oxides by transport, a.c. susceptibility, torque magnetometry and high-field ESR***.**

Recent relevant publications:

1.)N.E. Hussey et al., “A coherent three-dimensional Fermi surface in a high-transition-temperature superconductor”., Nature 425, 814 (2003);

2.) A.P. Mackenzie et al, “The superconductivity of Sr2RuO4 and the physics of spin-triplet pairing”, Rev. Mod. Phys 75, 657 (2003);

3.) S.A. Grigera et al., “Magnetic-field tuned quantum criticality in the metallic ruthenate Sr3Ru2O7”. Science 294, 329 (2001).

Principal researcher: **Prof. G. Lonzarich, Dr. S.S. Saxena**: Low Temperature Physics Group, Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, Tel: +44 (0)1223 337351, Fax: +44 (0)1223 337351, e-mail: ggl1@phy.cam.ac.uk

Quasiparticle pairing and transport on the border of metallic antiferromagnetism and on the border of itinerant-electron ferromagnetism in narrow band metals; first order quantum phase transitions; unconventional forms of charge, spin and current order near QCP.

Recent relevant publications:

1) N. Doiron-Leyraud, et al., “Fermi-liquid breakdown in the paramagnetic phase of a pure metal”, Nature 425 (2003) 595;

2) K. G. Sandeman, G. G. Lonzarich & A. J. Schofield, “Ferromagnetic superconductivity driven by changing Fermi surface topology”, Phys. Rev. Lett. 90 (2003) 167005;

3) P. Monthoux & G. G. Lonzarich, “Density-fluctuation-mediated superconductivity”, Phys. Rev. B 69 (2004) 064517.

Principal researcher: **Prof. B. Rainford**, School of Physics and Astronomy, University of Southampton, Highfield, Southampton, SO17 1BJ, Tel: +44 (0)23 8059 2094, Fax: +44 (0)23 8059 3910, e-mail: B.D.Rainford@soton.ac.uk

Spin dynamics of systems close to QPT using inelastic neutron scattering and μ*SR, including NFL scaling of the dynamical response; interaction between topological frustration and moment formation in* β*-Mn,* YMn_2 *and related compounds; low dimensional correlations in* RMn_4Al_8*; NFL scaling studies of M(B,T), Cp(B,T) and spin dynamics in candidate quadrupolar Kondo systems; dynamics and thermodynamics of anisotropic Kondo systems.*