CompStar School and Workshop 2008

The Complex Physics of Compact Stars

Lądek Zdrój (Poland), 18.-29. Feb. 2008

Summary

This meeting was the first in a series of activities devoted to the development of a European research and training network on "The Physics of Compact Stars". It consisted of a one-week school for young scientists followed by a 4-day workshop devoted to the multifaceted topic of Compact Star physics. While the school provided lectures introducing the main fields of compact star research, the workshop brought together leading experts in the field, in order coordinate networking projects with the goal of creating a European research area for "astronuclear physics".

Description of the scientific content and discussions at the event

Over the last decade, compact stars have been shown to be excellent tools to test fundamental properties of gravity and matter under extreme conditions. The new generation of space X-ray and gamma-ray observatories are enabling new observations and breakthrough discoveries (kHz quasi- periodic oscillations, bursting millisecond pulsars, half-day long X-ray superbursts). The thermal emission from isolated neutron stars has provided important information on their radii and cooling history. At the same time, improvements in radio telescopes and interferometric techniques have increased the number of known binary pulsars, allowing for extremely precise neutron star mass measurements and tests of general relativity. Finally, a large multinational effort has taken place in the last decade to build detectors, offering the exciting prospect of the detection of gravitational waves. We are thus experiencing the blooming of astronuclear physics, an exciting research area in which the physics of compact stars plays a fundamental role. While a part of this physics relies on theories that are well tested in terrestrial laboratories, a good part of it is basically unknown in the regimes found in compact stars. Unveiling this picture is a task made challenging by the multidisciplinary character of the problem, which requires expertise from historically independent disciplines, such as nuclear and particle physics, astrophysics, gravitational and computational physics. It is a task to which the newly founded ESF research networking programme "CompStar" devotes its activities and to which, in particular, this first meeting aimed to contribute with both its parts, the school and the workshop.
In order to fulfill the twofold goal of the networking, namely (A) to educate a young generation of scientists in the interdisciplinary field of astronuclear physics and (B) to achieve qualitative progress in the frontier research on the relationships between astrophysics of compact star related phenomena and microphysics of dense, strongly interacting matter, the meeting was divided in two parts: (A) a school and (B) a research workshop. Owing to the initializing role of this first meeting, the topics of the lectures at the school and of the talks at the workshop both covered all the main directions of the proposed research.

The school week was covered by the following invited lecturers and topics:

- Roberto Turolla (Padova, Italy): Observation of Compact Star Properties
- Sanjay Reddy (Los Alamos, USA): Supernova Neutrinos and the Evolution of Protoneutron Stars
- Pawel Haensel (Warsaw, Poland): The crust (Nuclear and plasma physics)
- Michael Buballa (Darmstadt, Germany): The inner core (QCD matter)
- Dima Yakovlev (St. Petersburg, Russia): Cooling of Compact Stars
- Nikolaos Stergioulas (Thessaloniki, Greece): Compact stars as sources for gravitational waves

Each lecturer had given 4 hours of lectures and two hours of exercises. The definition of homework problems and the discussion of their solution in a seminaristic style qualifies a good school. In this spirit, the school contributed modern educational material useful for this and coming generations of students in the field.

The workshop focussed on the topical research directions as defined in the CompStar research proposal, and broke them down into sessions (in brackets):

- Nuclear Physics Aspects of Compact Stars (EoS and Structure; Crust physics, vortices
- Impact of Structure of Matter on the Astrophysical Evolution of Compact Stars and vice versa (Phenomenology, Cooling, Rotation,
- QCD phase transitions in Compact Stars (EoS, Color supeconductivity, Vortices)
- Gravitational wave emission from single and binary Compact Stars (Supernovae and binaries; Pillars)

Two panel discussions were organized in order to formulate the most urgent questions for the networking between the three communities of: 1) dense matter physics, 2) gravitational theory and 3) astrophysical modeling and to derive tasks for the future work.

The first panel was devoted to "Equation of State (EoS) and Compact Star Structure" and the main problem was the status of the theoretical description of strongly interacting matter at high densities in the compact star core, where QCD degrees of freedom can occur in different phases, e.g., as color superconducting quark matter. One unresolved question is whether strangeness at high densities occurs in the form of heavy hadronic degrees of freedom (hyperons) or in the form of deconfined strange quark matter. Another question is: Can one exclude on theoretical and/or observational grounds that strange quark matter forms the absolute ground state with lowest energy and that the hypothetical selfbound compact objects consisting of this form of matter coulod exist? A systematic investigation of QCD degrees of freedom in different alternative hybrid EoS for the simulation of supernova collapse and protoneutron star formation has been agreed between groups in Frankfurt (Schaffner-Bielich, Sagert, Hempel), Wroclaw (Blaschke, Sandin, Lastowiecki) and Basel (Fischer, Liebendoerfer).

The second panel was devoted to the question of "Compact star evolution", in particular due to spin-down and cooling but also due to mass accretion from a in low-mass companion star in binary systems, showing active and qiescent phases of X-ray burst activity. The latter objects turn out to be extremely important for constraining our knowledge on the physical properties of low-denisty nuclear matter in the compact star crust. The role of superfluid phases of nuclear/quark matter for phenomena like glitches and high-spin pulsars with millisecond rotation periods has been discussed vividly. It was decided to devote specific workshops and even a school to the problem of crust physics as a proper understanding is inevitable for interpretation of most types of compact star observations.

The program was completed by a historical perspective on the very birth of the idea of "neutron stars" in which Lev Landau, the famous founder and head of a russian school of theoretical physicists was involved (given by Dima Yakovlev) and a presentation of the European Science Foundation with special focus on research networking programmes (given by Thibaut Lery).

Besides its scientific part, this meeting provided a good basis for developing personal contacts within the network, for students as well as researchers and between them.

Assessment of the results and impact of the event on the future direction of the field

At the school basis knowledge for compact star physics taught to first generation of PhD students from CompStar member countries and associated partner groups. On purpose, the full spectrum was covered this time while later events shall be devoted to in-depth teaching on particular aspects of this interdisciplinary subject.

At the workshop, the agenda for the directions of research was set in individual as well as panel discussions. New collaboration links have been estabiliched and work plans have been staged. From the community of numerical relativity the request for realistic EoS and improved data on relevant thermal and transport properties of compact star matter has been formulated. In the course of its further activities, the RNP should use its scientific potential to coordinate research efforts of the diverse member groups from the dense matter community with their individual field of expertise towards the goal of delivering a usable EoS with state-of-the-art inputs in all branches of the vast parameter space required for astrophysical applications as, e.g., for modelling supernovae or compact star mergers. Plans for short visits between expert groups as well as exchange of PhD students have been agreed.

Final programme of the meeting

School Program

Time	MONDAY 18.02.	TUESDAY 19.02.	WEDNESDAY 20.02.	THURSDAY 21.02.	FRIDAY 22.02.	SATURDAY 23.02.
08:30 - 08:55	Breakfast					
09:00 - 09:55	Turolla	Reddy	Haensel	Yakovlev	Buballa	Stergioulas
09:55 - 10:05	Break					
10:05 - 11:00	Turolla	Reddy	Haensel	Yakovlev	Buballa	Stergioulas
11:00 - 11:30	Coffee break					
11:30 - 12:25	Reddy	Turolla	Yakovlev	Haensel	Stergioulas	Buballa
12:25 - 12:35	Break					
12:35 - 13:30	Reddy	Turolla	Yakovlev	Haensel	Stergioulas	Buballa
13:30 - 14:30	Lunch break					
	Study time					
16:00 - 17:00	Turolla					
17:00 - 18:00	Reddy				Buballa	
13:30 - 14:30	Dinner break				Stergioulas	Dinner break
19:00 - 20:00		Reddy	Haensel	Yakovlev		Stergioulas
20:00 - 21:00	Cheese and	Turolla	Yakovlev	Haensel	Conference	Buballa
21:00 -	Wine Party		Sausage and Beer Party		Dinner	

School lectures:

R. Turolla (Padova, Italy)	Observation of Compact Star Properties
S. Reddy (Los Alamos, USA)	The Birth of Compact Stars: Supernovae and Protoneutron Stars
P. Haensel (Warsaw, Poland)	The Crust (Nuclear and Plasma Physics)
D. Yakovlev (St. Petersburg, Russia)	Cooling of Compact Stars
M. Buballa (Darmstadt, Germany)	The Inner Core (QCD Matter)
N. Stergioulas (Thessaloniki, Greece)	Compact Stars as Sources for Gravitational Waves

Workshop Program

Time	MONDAY 25.02.	TUESDAY 26.02.	WEDNESDAY 27.02.	THURSDAY 28.02.	FRIDAY 29.02.
08:30 - 08:55	Breakfast				
09:00 - 11:00	Opening SN+BINARIES Fischer Giacomazzo Drago	EOS+STRUCTURE Sagert Pederiva Wolter Vidaña	COOLING Margueron Haensel Grigorian Henderson	CRUST Samuelsson Newton Wlazłowski Providencia	SC Meeting
11:00 - 11:25	Coffee break				
11:30 - 13:30	SN+BINARIES Patruno Bulik Fantina Arcones	EOS+STRUCTURE Schulze Kubis Pagliara Sandin	ROTATION Zdunik Beijger Steijner Alloy	VORTICES Pethick Chamel Shahabasyan Glampedakis	SC Meeting
13:30 - 14:55	Lunch break				
15:00 - 15:55	Weaving the Network				THE END
16:00 - 18:00	PHENOMENOLOGY Popov Schaffner-Bielich Sedrakian Dexheimer	COLOR SUPERC. Oertel Grunfeld Anglani Cordeiro	EOS SPECIAL Röpke Hempel Tolos Arumugam	PILLARS Rezzolla Pons SUMMARY	
18:00 - 18:55	Dinner break				
19:00 - 20:00	Yakovlev: “Landau and Neutron Stars”	Panel Discussion ”EoS+Structure”	Panel Discussion ”Evolution”	ESF Pres.	
20:00 -	Get-Together Evening	(Blaschke, Schaffner, ...)	(Haensel, Popov, ...)	Farewell	

List of contributions:

1	Alloy	Neutron stars with electric field
2	Anglani	Mesons and diquarks in the 2SC phase
3	Arcones	Neutrino-driven winds
4	Arumugam	EoS from relativistic Mean Field Theory
5	Bejger	Crustal rigidity and rotational deformation of neutron stars
6	Bulik	Properties of binary compact objects: observations and evolutionary calculations
7	Chamel	Superfluid models of neutron stars
8	Cordeiro	Two-level pairing model in the Schwinger representation
9	Dexheimer	Protoneutron and Neutron Stars
10	Drago	Quark matter formation and astrophysical explosions
11	Fantina	Type II supernovae: weak processes and dynamics of gravitational collapse
12	Fischer	On the possible fate of massive progenitor stars
13	Giacomazzo	Simulating Binary Neutron Star Mergers with Whiskey
14	Glampedakis	Do superfluid instabilities prevent NS precession?
15	Grigorian	Cooling of hybrid neutron stars
16	Grunfeld	Color neutrality effects in the phase diagram of the PNJL model
17	Haensel	Deep crustal heating and Soft X-ray Transients
18	Hempel	A statistical model for hot hadronic matter
19	Henderson	Finite Difference Modelling of Heat Transport within Compact Stars
20	Kubis	Neutron stars with non-homogeneous core
21	Margueron	Neutron pairs in nuclear matter and in nuclei
22	Newton	Transition from homogeneous to inhomogeneous matter in the NS crust
23	Oertel	Surface effects in CFL strangelets and strange stars
24	Pagliara	Stability of CFL cores in Hybrid Stars
25	Patruno	Observations of LMXBs and accreting millisecond pulsars
26	Pederiva	Recent progress on the computation of the EoS of neutron and nuclear matter with AF diffusion MC
27	Pethick	Vortices in rotating BE condensates
28	Pons	Prospects of inferring dense matter properties from NS Cooling: the magnetar masquerade
29	Popov	Space cowboys odyssey: beyond the Gould belt
30	Providencia	Compact star crust: relativistic versus Skyrme nuclear models
31	Rezzolla	Modelling the dynamics and GW-emission of NS binaries
32	Röpke	Light clusters in the EoS for core-collapse supernovae
33	Sagert	Soft EoS from HI data and implications for neutron stars
34	Samuelsson	Effects of the superfluid neutrons on the dynamics of the crust
35	Sandin	Superconducting quark core of protoneutron stars
36	Schaffner-Bielich	Hunting down exotic matter in compact stars: mass versus radius measurements
37	Schulze	Hadron-Quark Phase Transition in Hyperon Stars
38	Sedrakian	Neutrino interactions in nuclear and quark matter
39	Shahabasyan	Fluctuational Appearance of Proton Vortices in the Superfluid NS Core
40	Stejner	Signature of deconfinement during spin down in cooling hybrid stars
41	Tolos	Equation of state from low-momentum interactions
42	Vidaña	Spinodal instabilities within the Brueckner-Hartree-Fock approach
43	Wlazłowski	Quantum Monte Carlo study of strongly correlated fermionic gases
44	Wolter	Constraints on the Symmetry Energy from Heavy Ion Collisions
45	Yakovlev	Landau and neutron stars
46	Zdunik	Rapidly rotating compact stars

CFL - Color-flavor-locked
CS - Compact Star
EoS - Equation of State
MC - Monte Carlo
NS - Neutron Star
PNJL - Polyakov-Loop Nambu–Jona-Lasinio