# Compstar: School and Workshop 2009
# The crust of compact stars and beyond


## Abstract

Compstar 2009, a winter school followed by a three-day workshop, was the second of a series of five meetings that the RNP Compstar has planned. It took place in the Department of Physics, University of Coimbra from the 5th to the 13th February. The focus of the school, 5-10 February, was on the crust properties of compact stars. It consisted of twelve main lectures of 1h30m, six discussion meetings, a poster session and a colloquium at the Science Museum hall, opened to the city. The workshop was dedicated to the physics of compact stars in general with four review talks of 40 min , 30 short talks of 25 min and a discussion meeting. A total of 83 participants from 22 countries attended the event. From these, 52 were master or Ph. D. students or young post-doctoral researchers. Information about the program, participants, lectures, and poster and oral contributions is online at http://nautilus.fis.uc.pt/compstar/


## Description of the scientific content of and discussion at the event

The winter school took place during the first seven days of the event and covered several topics essential to understand the physics of the crust of compact stars, namely the following topics: superfluidity, glitches, neutrino processes, the physics of pasta phases, molecular dynamics simulations of neutron star and nuclear pasta, transport properties, strange crusts, magneto-thermal evolution of neutron stars and observational evidences. Due to the absence of Valeri Hambaryan we did not have any expert on observation of neutron stars. This was a weak point that we expect to overcome in the next meeting with the invitation of several observational experts.

The lectures were followed by sessions during which concrete problems were solved or unclear/hot points discussed. These periods were of particular importance for the students. Students had also the opportunity to present and discuss their work during a poster session. The lectures and posters are all online on the site of the meeting.

The school was followed by a three day workshop on the physics of compact star in general. We have covered most of the fields of interest to the RNP, namely:

- Nuclear Physics Aspects of Compact Stars; their impact on the Astrophysical Evolution of Compact Stars and vice versa
- Properties of QCD in compact Stars and phase transitions that could take place in their interior
- Gravitational wave emission from single and binary Compact Stars

In particular there were four review talks on the crust and superfluidity (Jérôme Margueron), magnetic fields and magnetars (Sanjay Reddy), dense matter and exotic degrees of freedom (David Blaschke), neutron stars and gravitational waves (Ian Jones). The review talks were followed by several short talks on the same topic (all online in the site of the meeting). Some other topics also covered were: collective modes, neutron matter, low density matter, crust and pasta structures, supernovae and proto-neutron stars. A round table on the second day was chaired by Pierre Pizzochero and focused on the open issues of compstars and on the possible observations which could help ruling out models and scenarios not compatible with them. A summary of the main topics and questions that were pointed out and addressed in the round table follows:

- it is important to understand whether the curst of accretted matter is ordered (existence of cristal or quasicristal phases), as it is obtained in calculations by C. Horowitz. This would mean the conductivity is high.

- it would be desirable that in the next few years there will be calculations that show how the magnetic field is formed inside a neutron star, how it evolves, how stable and how strong it is in the liquid interior.

- the calculation of quantities such as the shear modulus and breaking strength are important to understand gravitational wave emission.

- how to include the pasta phases in the calculation of shear modulus and other crust properties ? It would be also very interesting to study how important are exotic pasta phases for the breaking strength. What information could we get for the pasta phase from liquid crystals?

- it would be important that theorists work on an unified description of both the equation of state and transport properties. That point is very callenging and unfortunatelly still missing. Outputs of theorist should be determined with error bars.

- it is necessary to perform realistic simulations of the thermal relaxation of neutron stars which explain the observations.

- which are the crucial observables to discriminate the existence or not of pasta phases?

- do exotic degrees of freedom like hyperons or quark matter really exist in the neutron star interior? There is still no general consensus about this point.

- what is the origin of the timing noise in radio pulsars ?

- rapid rotating transient sources (RATS) were discovered 3 or 4 years ago, not far from the magnetar region in the $P/\dot{P}$ diagram. What information can we get from RATS?

- very much expected data from Fermi Gamma-ray Space Telescope is starting to be collected in February 2009.
- several scenarios for glitchs (starquakes versus superfluid vortices) and their relation with the size of the crust were discussed.
- crucial information on the neutron skin thickness in $^{208}$Pb and on the nuclear symmetry energy and, therefore, a possible indirect measurement of the neutron star crust thickness, is expected from the parity radius experiment (PREX) experiment at JLAB.
- the magnetic field must be taken into account in neutron star cooling calculations.
- how can we use data from exotic radioactive beams in order to constraint more the isospin dependence of the nuclear matter equation of state ?

**Lectures**

Lectures at the School "The Crust of compact stars" (5-10 February 2009) Dr. Valeri Hambaryan from the Jena University could not come due to a strong flu and was substituted by Jérôme Margueron from IPN, Orsay, Paris.

1. Christopher Pethick (NORDITA)

   Lec 1 : Basic physics of pasta phases

   Lec 2 : Superfluidity, superconductivity, vortices and glitches

   Lec 3 : Neutrino processes

2. Charles Horowitz (Indiana University)
   Molecular dynamics simulations of neutron star and nuclear pasta:

   Lec 1 : Neutron star crust, coulomb plasmas and molecular dynamics simulations.

   Lec 2 : Calculating transport properties such as neutrino opacity, thermal conductivity or shear viscosity from MD simulations.

   Lec 3 : Complex nuclear pasta phases.

3. Ulrich Geppert (Institute for Space Systems, Berlin)
   Magneto-thermal evolution of neutron stars

   Lec. 1 : Observational evidences: rotation, thermal and MF evolution

   Lec. 2 : Attempts to understand the observations of rotation, thermal and MF evolution

4. Sanday Reddy (Los Alamos National Laboratory)

   Lec. 1 : Strange crusts

Lec. 2 : Superfluid aspects of the thermal conductivity in the crust

5. Jérôme Margueron,(IPN, Orsay, Paris)

Lec. 2 : Neutron star observations in X-rays;

Lec. 2 : Neutron stars and properties of nuclei.

There were 65 participants during the school.

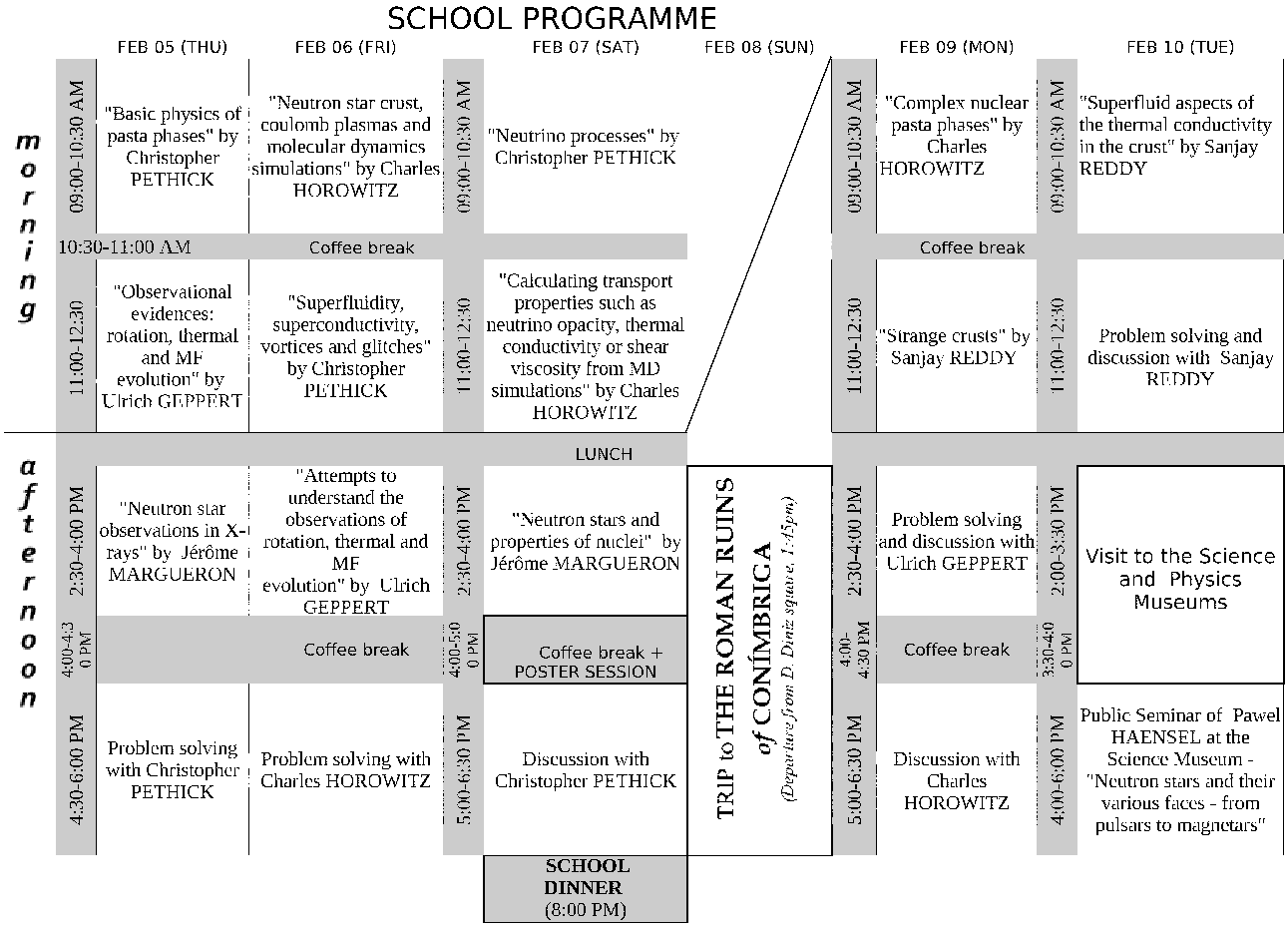
## Assessment of the results and impact of the event on the future direction of the field

During the present meeting it was possible to see the importance of the RNP: students are being supervised by elements of different research centres/countries, collaborations have started or were strengthened since there was plenty of time for discussions and exchange of ideas. It is important that the RNP finances short visits which allow to complete the interchange between the different institutions inside or outside the net.

The discussion meetings were important to define which priorities should be taken and which observations/measures would help the field. In particular, it was pointed out once more the importance of knowing the radius and the mass of neutron stars. Also, the problems/suggestions raised during the round table are open problems whose solution would bring important progress in the field. A clear impact of the Compstar meetings will be seen in the future by the number of papers in the field published within the network, the size of the collaborations involved and the interdisciplinarity of the research developed.

# Final programme of the meeting

## School Program



# Workshop Program

## WORKSHOP PROGRAMME

| | | FEB 11 (WED) | | FEB 12 (THU) | | FEB 13 (FRI) |
|---|---|---|---|---|---|---|
| | 08:45-09:00 AM | OPENING SESSION | | | | |
| morning | 9:00-10:30 AM | Crust & Superfluidity<br><br>MARGUERON, Jérôme (40')<br>ILLARIONOV, Alexey (25')<br>CHAMEL, Nicolas (25') | 9:00-10:30 AM | Magnetic fields & Magnetars<br><br>REDDY, Sanjay (40')<br>CERDA-DURAN, Pablo (25')<br>SOTANI, Hajime (25') | 9:00-10:30 AM | Dense Matter & Exotic d.o.f.<br><br>BLASCHKE, David (40')<br>DEXHEIMER, Veronica (25')<br>SANDIN, Fredrik (25') |
| | 10:30-11:00 AM | **Coffee break** | | | | |
| | 11:00-12:40 | Crust & Pasta Structures<br><br>HOROWITZ, Charles (25')<br>MARUYAMA, Toshiki (25')<br>NEWTON, William (25')<br>SEBILLE, Francois (25') | 11:00-12:40 | Magnetic fields & Magnetars<br><br>MENEZES, Débora (25')<br>PEREZ-GARCIA, M.Angeles(25')<br>GLAMPEDAKIS, Kostas(25')<br>CUOFANO, Carmine (25') | 11:00-12:40 | Dense Matter & Exotic d.o.f.<br><br>HAENSEL, Pawel (25')<br>BEIJGER, Michal (25')<br>READ, Jocelyn (25')<br>TURKO, Ludwik (25') |
| | | LUNCH | | | | |
| afternoon | 3:00-4:15 PM | Supernovae & Proto neutron stars<br><br>ARCONES, Almudena (25')<br>RöPKE, Gerd (25')<br>HEMPEL, Matthias (25') | 3:00-4:15 PM | Collective Modes<br><br>DUCOIN, Camille (25')<br>KANTOR, Elena (25')<br>CHUGUNOV, Andrey (25') | 3:00-4:30 PM | Neutron Stars & G.Waves<br><br>JONES, Ian (40')<br>HASKELL, Brynmor (25')<br>**CLOSING SESSION**<br>(David Blaschke) |
| | 4:40-5:10 PM | **coffee break** | 4:15-4:45 PM | **coffee break** | 04:30-5:00 PM | **coffee break – END of WORKSHOP** |
| | 5:10-6:25 PM | Low density matter<br><br>STONE, Jirina (25')<br>VIñAS, Xavier (25')<br>GRYGOROV, Pavlo (25') | 4:45-5:35 PM | Neutron Matter<br><br>POLLS, Arturo (25')<br>BALDO, Marcello (25') | 05:00 PM | **Meeting of the Steering Committee** |
| | | | 5:45-7:15 PM | **Round Table** | | |
| | 09:30 PM | **CONCERT at the UNIVERSITY CHAPEL** | 08:00 PM | **SOCIAL DINNER at JUSTIÇA e PAZ** | | |

## Workshop Talks

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|---|---|
| ARCONES, Dr. Almudena | Influence of light nuclei on neutrino-driven supernova outflows |
| BALDO, Prof. Marcello | Neutron matter at very low density |
| BEIJGER, Dr. Michal | Rotating NSs dynamical mini-collapses & instabilities induced by phase transitions |
| BLASCHKE, Prof. David | Structure and cooling of compact stars with color superconductivity |
| CERDA-DURAN, Dr. Pablo | Alfven QPOs in Magnetars in the anelastic approximation |
| CHAMEL, Dr. Nicolas | Superfluidity in neutron star crusts |
| CHUGUNOV, Dr. Andrey | Plasma screening enhancement of fusion reactions in dense matter |
| CUOFANO, Dr. Carmine | R-modes and magnetic field evolution in rapidly rotating neutron stars |
| DEXHEIMER, Ms. Veronica | Neutron Stars as a Probe for Dense Matter |
| DUCOIN, Dr. Camille | Elementary excitations in the outer core of neutron stars |
| GLAMPEDAKIS, Dr. Kostas | Superfluid signatures in magnetar seismology |
| GRYGOROV, Mr. Pavlo | Microscopical description of the crust of neutron stars |
| HAENSEL, Prof. Pawel | Entraiment in superfluid nucleon-hyperon cores of neutron stars |
| HASKELL, Dr. Brynmor | Oscillations of superfluid neutron stars |
| HEMPEL, Mr. Matthias | A Statistical Model for Hot Hadronic Matter |
| HOROWITZ, Prof. Charles | Molecular dynamics simulations of the crust of accreting neutron stars |
| ILLARIONOV, Dr. Alexey | TBA: Spatial structure of the s-wave superfluidity |
| JONES, Dr. Ian | Gravitational wave emission from superfluid neutron stars |
| KANTOR, Ms. Elena | Damping times for a radially pulsating superfluid NS at a finite T |
| MARGUERON, Dr. Jrme | Superfluid properties of the crust |
| MARUYAMA, Dr. Toshiki | Property of non-uniform nuclear matter at finite temperature |
| MENEZES, Dr. Dbora | Strong magnetic fields in quark matter |
| NEWTON, Dr. William | Modeling The Inner Crust with the Hartree-Fock Method |
| PEREZ-GARCIA, Dr. M. Angeles | Fermi liquids in neutron stars |
| POLLS, Prof. Arturo | Hot neutron matter from a Self-Consistent Greens Functions approach |
| READ, Dr. Jocelyn | Constraining a phenomological equation of state for neutron star cores |
| REDDY, Sanjay | Superfluid heat conduction |
| RÖPKE, Prof. Gerd | Low-density EOS and Appearance of Light Clusters in Post-bounce Evolution of Core-Collapse Supernovae |
| SANDIN, Dr. Fredrik | Neutron stars as probes of mirror dark matter |
| SEBILLE, Prof. Francois | Dynamical mean-field investigation of exotic structures in isospin asymmetric nuclear matter |
| SOTANI, Dr. Hajime | Alfven Oscillations in Magnetars |
| STONE, Prof. Jirina | EOS of the pasta phase and its dependence on the choice of nucleonnucleon interaction |
| TURKO, Prof. Ludwik | Color neutrality problem in effective QCD models |
| VIñAS, Prof. Xavier | Nuclear symmetry energy probed by neutron skin thickness of nuclei |

## Posters

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|---|---|
| BLOTTIAU, Dr. Patrick | Role of microphysics in type II supernovae evolution |
| GUSAKOV, Dr. Mikhail | Damping of sound waves in superfluid nucleon-hyperon matter of NSs |
| KUBIS, Dr. Sebastian | Symmetry energy effects in the NS crust properties |
| LENZI, Mr. Csar | Determination of the NS structure using narrow-band GW detector |
| MALHEIRO, Prof. Manuel | Color Superconductivity and Confinement in the Chromodielectric |
| MARRANGHELLO, Dr. Guilherme | Model Gravitational wave background from NS phase transition |
| PAIS, Ms. Helena | Quark Stars in a strong magnetic field |
| RABHI, Dr. Aziz | Spinodal instabilities and the distillation effect in nuclear matter under strong magnetic fields |
| ROCA MAZA, Mr. Xavier | Sensitivity of the properties of the outer crust of NS to the density dependence of the symmetry energy |
| SANTOS, Dr. Alexandre | Low density instabilities in asymmetric nuclear matter within QMC with $\delta$-meson |
| SOMA, Mr. Vittorio | Modification of nuclear matter properties induced by 3-body forces |
| TURLIONE, Ms. Anabela | Cooling of neutron stars with a quark matter core |