Swiss National Science Foundation

International Cooperation

SCOPES 2009-2012

Guidelines for interim scientific reports (JRP/IP)

The interim report must be submitted to the SNSF by the project co-ordinator (**electronically and in print**). It should cover **the whole period since the start of the project** (previous interim reports should be included in summarised form).

1. General Information

1.1 Number of the JRP/IP "Synthesis of heavy elements in core collapse supernovae and their imprint on galactic chemical evolution"
1.2 Number of the JRP/IP **IZ73Z0 128180**
1.3 Name of co-ordinator and partner teams
Principal Applicant Thielemann Friedrich K., Basel
Co-applicant(s)
Charbonnel Corinne, Versoix
Mishenina Tamara V., Odessa
Panov Igor V., Moscow

2. Overview of (research) activities

2.1 Which work has been carried out by each of the teams?

Have the activities been in accordance with the scientific and technical description in the application?

The summary of the initial proposal lists a number of related research topics to be addressed during the term of this Scopes Project. In the second year, based on the initially established plan, we worked on the following astrophysical problems:

- hydrodynamic (neutrino-)radiation transport calculations of core-collapse supernovae with new presupernova models (milestone 2);
- Numerical simulations of shock-breakout in supernovae, based on multigroup radiation transfer, coupled to hydrodynamics (milestone 7b);
- Equation of state descriptions at extreme densities, combining the quark-hadron phase transition, an excluded-volume approximation, as well as the inclusion of light clusters, were developed for the implementation in supernova simulations. (milestone 2 and additional activities beyond originally planned tasks);
- Consistent r-process calculations for the main r-process, including the extension of calculations until late times of the neutrino-driven wind and tests of alternatives like polar jet-ejection in rotating models (including magnetohydrodynamic effects) in order to produce the heaviest r-process nuclei (milestone 3b);
- Using phenomenological approaches to spontaneous fission and its application to the

r-process. Testing the influence of models for spontaneous fission rates and other predictions of nuclear properties on the formation of superheavy elements (milestones 1 and 3a);

- Modeling of non-LTE line formation for heavy elements in stellar atmospheres, (milestones 4 and 7a);
- Determination of element abundances in old stars over a large range of metallicities, in order to provide a data base for the history of abundance ratios of heavy (neutron-capture) elements during the evolution of the Galaxy (milestone 5);
- Determination of stellar ages for different metallicities via the decay pattern of actinide abundances (milestone 5);
- Galactic chemical evolution calculations, based on the ejected abundance yields from nucleosynthesis predictions, and comparison with our observational results, testing the enrichment pattern of stellar populations in the Galaxy at different evolutionary times and distances (milestone 6 and 5).

These activities were part of seven milestones mentioned in the original proposal:

Milestone	**Associated activity**	**Expected duration**	**Responsible project partner**	**completion**
1a	Neutron-induced reaction rates	1 year	Partner 1,3	100%
1b	Spontaneous and delayed fission	1 year	Partner 1,3	70%
2	Neutrino transport and supernova models	3 years	Partner 1,3	60%
3a	Phenomenological tests for nucleosynthesis	2 years	Partner 1,3	90%
3b	Nucleosynthesis in consistent models	3 years	Partner 1,3	70%
4	atomic input for spectrum modeling	2 years	Partner 2,3,4	100%
5	abundance determination of spectra	3 years	Partner 2,3,4	80%
6	incorporation of nucleosynthesis predictions in chemical evolution models	3years	Partner 2	70%
7a	Different NLTE effects	2years	Partner 3,4	100%
7b	shock-breakout with relativistic effects	2years	Partner 1,3	90%

*** 1=Basel; 2=Geneva; 3=Russian partner; 4=Ukrainian partner**

The results obtained during the second year are summarized in the following, also pointing out the progress with respect to milestones listed above. The indices I through VII are not always directly linked to the milestones repeated here, but relate rather to subgroups of all four participating institutions. I and II cover observations and their analysis by groups at Odessa and Moscow observatories, III-V relate to activities perfomed at ITEP Moscow, VI and VII list the contributing activities of the Basel and Geneva groups. *As the support for Basel and Geneva is mostly related to travel and the exchange of ideas with the groups from eastern Europe, the latter two activities are presented in a shorter way and more selectively. They appear anyway as part of annual reports of the regular SNF grants of these groups. But we mention specifically the projects of joint nature, where a real collaboration got started or is intended.*

I.The Galaxy: Chemical evolution studies and NLTE effects (Institute of Astronomy, Moscow; Odessa Observatory)

I.1. L. Mashonkina constructed a comprehensive model atom for Pb I using the energy levels from laboratory measurements (Wood & Andrew, 1968, JOSA, 58, 818; Brown et al. 1977, JOSA, 67, 1240; Hasegawa & Suzuki, 1996, Phys. Rev. A53, 3014) and also from atomic structure calculations using the Cowan code (Alexander Ryabtsev, private communication). Experimental photoinization cross-sections were used for the ground state of Pb I (Heppinstall & Marr, 1969, Proc. Roy. Soc. A310, 35) and hydrogenic approximation for the remaining levels to compute radiative rates for the bound-free (b-f) transitions. Transition probabilities were taken from Biemont et al. (2000, MNRAS, 312, 116) where available and from the calculations of Alexander Ryabtsev. Theoretical approximation formulas were employed to compute collisional rates.
The non-local thermodynamic equilibrium (NLTE) line formation for Pb I in stellar atmospheres was considered for the first time. The calculations were performed for the grid of model atmospheres representing the atmospheres of the Sun and the sample of metal-poor stars with effective temperatures $T_{\rm eff}$ = 4000-6000 K, surface gravities log g = 0-4.6, and metallicities ranging between [Fe/H] = -0.6 and [Fe/H] = -3. It was found that the main non-LTE mechanism for Pb I is the ultraviolet overionization. NLTE leads to systematically depleted total absorption in the Pb I lines and accordingly, positive abundance corrections $\Delta_{\rm NLTE}$. The departures from LTE grow with decreasing metallicity, such that $\Delta_{\rm NLTE}$ of Pb I 4057 Å increases from 0.16 dex in the 5780/4.44/0 model up to 0.56 dex in 4825/1.5/-2.9.
The NLTE method was applied to revise the Pb abundance for the Sun. With the Holweger & Mueller (1974, Sol. Phys., 39, 19) model atmosphere, log $\varepsilon_{\rm Sun}$(Pb) = 2.09, in good agreement with the meteoritic lead abundance log $\varepsilon_{\rm met}$(Pb) = 2.06 (Lodders et al. 2009, Landolt-Boernstein - Group VI Astronomy and Astrophysics Numerical Data and Functional Relationships in Science and Technology Volume 4B: Solar System. Edit. J.E. Trümper, 44). For comparison, a 0.13 dex lower element abundance was obtained under the LTE assumption.
The next step was to revise the Pb and Eu abundances available in the literature and to constrain the Pb production mechanisms in the early Galaxy (Mashonkina, Sitnova). We used the data of Roederer et al. (2010, ApJ, 724, 975), obtained under the LTE assumption for the metal-poor stellar sample. It was found that, in NLTE, the two strongly r-process enhanced (r-II) stars have very similar Pb/Eu abundance ratios, with the mean log ε(Pb) = 0.68±0.01, and the waiting-point r-process model of Kratz et al. (2007, ApJ, 662, 39) reproduces the observations very well. The revised Pb/Eu abundance ratios of the r-II stars match, within the error bars, the corresponding solar r-process ratio. Thus, the universality of the r-process has been proven not only for the second r-process peak elements from Ba to Hf as found earlier (see Sneden et al. 2008, ARAA, 46, 241 and references therein) but also for the heavier element Pb. The stars in the -2.3 < [Fe/H] < -1.4 metallicity range have, on average, 0.51 dex higher Pb/Eu abundance ratios compared with that of the strongly r-process enhanced stars. It was concluded that the s-process production of lead started as early as the time when Galactic metallicity had grown to [Fe/H] = -2.3. The average Pb/Eu abundance ratio of the mildly metal-poor stars, with -1.4 ≤ [Fe/H] ≤ -0.59, is very close to the corresponding Solar System value, in line with the theoretical predictions of Travaglio et al. (2001, ApJ, 549, 346) that AGB stars with [Fe/H] ≈ -1 provided the largest contribution to the solar abundance of s-nuclei of lead.

I.2. L. Mashonkina has built an atomic model for singly-ionized thorium using atomic data for the energy levels from laboratory measurements. The NLTE calculations for Th II were performed for the first time for the Sun and for a small grid of model atmospheres with [Fe/H] = -2 and -3. In contrast to Pb I, Th II is the majority species in the stellar parameter range that we have covered, and the main non-LTE mechanism for Th II is connected to the pumping transitions arising from the low-excitation levels, with $E_{\rm exc}$ < 1 eV. Overall, non-LTE leads to weakened Th II lines and positive non-LTE abundance corrections, however, Δ_{NLTE} nowhere exceeds 0.21 dex.

I.3. In order to derive strontium abundances, Andrievsky and Korotin elaborated an atomic model of Sr. The model consists of 44 levels of Sr II with n < 13 and l < 6, as well as the ground level of Sr III. For the two important terms 4d2D and 5p2P, the fine structure was taken into account. The 24 levels of Sr I were included in the model only for the particle number conservation, since in atmospheres of not very cool stars Sr exists preferentially in the form of Sr II. All the details concerning this model (atomic level characteristics, oscillator strengths of the b-b transition, photoinization cross-section, collisional transition rates, broadening parameters, used program code and results of the test calculations) can be found in A&A 530, 105 (2011). This model was applied to a sample of extremely metal-poor stars which are believed to be born at the very early stages of the Galactic evolution, and therefore their chemical abundances carry an important information about the first massive super- and hyper-novae stars that produced first atomic nuclei heavier than helium.

I.4. The NLTE barium abundances of 173 dwarf stars belonging to the thin and thick disks were found (Mishenina, Korotin). The average barium abundances in the thin and thick discs are 0.01 ± 0.08 and −0.03 ± 0.07, respectively. The comparison to the calculations of the Galactic chemical evolution by Serminato et al. was conducted. The trend obtained for the Ba abundance versus [Fe/H] suggests a complex barium production process in the thin and thick discs.

I.5. Andrievsky, Korotin and Mishenina investigated NLTE Ba abundances of the 20 red giants in the globular cluster NGC 6752. It was found that the intrinsic abundance spread between the individual cluster stars is small and can be explained in terms of uncertainties in the abundance determinations.

I.6. The NLTE approximation was applied to study the abundance anomalies in the poorly investigated stars called semi-regular variable stars of type "d" (SRd). They are K-G giants. Until present, there was a belief that these stars have a chemical composition typical of old halo objects. Having analyzed some representative stars of this class we, for the first time, showed that this class is not homogeneous. It consists of two subgroups, one with abundances typical of the halo population, and the second group shows solar-like abundances. Thus, the stars of this group are of the thick/thin disk population.

Points I.1-6 indicate a strong progress for **milestones 4, 5, 7a**.

I.7. The abundances of the radioactive element Th and the r–process element Eu were determined with the help of synthetic spectrum calculations (Mishenina, Korotin). We selected the stars that belong to different galactic populations according to the kinematic criteria and determined their stellar parameters. We found that the stars with high proper motions refer to different components of the Galaxy: thin disk, thick disk, and halo. The chemical composition ([Mg/Fe]= -0.2, [Ba/Fe] = -1.46) of the star BD+80◦ 245 located far from the galactic plane agrees with being part of the accreted halo. For the giant HD115444, we obtained [Fe/H] = −2.91, an underabundance of Mn, an overabundance of heavy metals from Ba to Dy, and especially a high excess of the r–process element europium: [Eu/Fe]=+1.26. In contrast to its chemical composition typical of halo stars, HD115444 belongs to the disc population according to its kinematic parameters.

I.8. In 2011 the analysis of a stellar sample of FGK dwarfs, belonging to the thin disk and thick disk of the Galaxy (-1.0 < [Fe/H] < 0.3) with detailed chemical abundances determined, was extended by Mishenina, Korotin, and Gorbaneva. The behavior of alpha-elements (O, Mg, Si,

Ca), the iron peak (Ni) and neutron-capture elements as a function of [Fe/H] was analyzed for different substructures of the Galaxy that were distinguished according to the kinematic criteria.
The obtained Y, Zr, Ba, La, and Eu abundances were compared (Mishenina, Korotin) with the chemical evolution computations of Serminato et al. (2009). The alpha-element abundances in both stellar populations increase with decreasing metallicity. The [Ni/Fe] abundance ratio is close to zero, with a small scatter. Different n-capture elements have different trends, which are, in turn, different for the thin disk and thick disk. This indicates the complexity of enrichment sources for these elements. For Zr, La, Eu, and, especially, for Ba, abundance trends cannot be described by only taking into account the s-process yields of low-mass AGB stars and r-process residuals. The Na, Al, Cu, and Zn abundances were derived in LTE approximation: the synthetic spectrum for the copper lines was calculated taking into account its hyper-fine structure. We analyzed abundances of these elements as a function of metallicity [Fe/H] for the stars of the galactic thin and thick disks and the Hercules moving group. The Cu abundances and their trend with metallicity are essentially the same for all the three studied sub-structures. The mean Al and Zn abundances are significantly different for the thin and thick disks.

Points I.7 and 8 underline the progress made for **milestone 5**.

II. Chemical abundances as a tool to investigate physical properties of stars (Odessa Observatory, Institute of Astronomy, Moscow)

II.1. Effective temperatures, surface gravities, Li abundances, and rotational velocities v sin i were determined for 150 stars (Mishenina, Chekhonadskikh). v sin i values were found through a calibration of the cross-correlation function. 100 stars among them reveal activity, and a large part of them are BY Dra type stars. The level of chromospheric and coronal activity of the target stars was evaluated through logR’HK index and the X-ray flux. The Li abundances were examined dependent on M_{bol}, T_{eff} , [Fe/H], v sin I, and the level of activity. It was found that the active stars show higher Li abundances. Lithium was detected in 62% of the stars with high levels of solar-type activity, whereas only in 31% of the low activity stars. The existence of correlations between stellar Li abundances, chromospheric activity logR’HK , and v sin i are confirmed.
The obtained results may indicate some additional specific mechanisms of lithium production or its surviving in the high activity stars which have been explored. The results confirm that the main causes of high stellar activity and detectable Li abundance are determined by fast axial rotation and young age, respectively.

II.2. The abundances of 56 chemical elements and upper limits of Li and Be abundances were determined in the star rho Pupis (Yushchenko). The abundance pattern of rho Pup was found to be similar to that of Am type stars. The dependencies of the relative abundances of chemical elements on the second ionization potentials of these elements show that the role of charge-exchange reactions cannot be neglected in the atmospheres of rho Pup and delta Sct. The abundances of chemical elements in the atmospheres of 140 A-F type stars were analyzed and the importance of charge-exchange reactions in the atmospheres of these stars was confirmed.

II.3. For the binary star ZZ Boo, the atmospheric parameters and chemical abundances of the components were found utilizing the iron line abundance analysis: the effective temperatures T_{eff} = 6860 K and 6930 K, the surface gravities log g = 3.72 and 3.84, the metallicities [Fe/H] = -0.11 and -0.03, and projected rotation velocities vsini = 11.9 km/s and 19.3 km/s for the primary and secondary components, respectively (Yushchenko). The abundances of 24 and 22 chemical elements were determined in the atmospheres of the components. The abundance pattern of the primary (cooler) component shows solar or slightly subsolar abundances of all elements. CNO abundances are close to solar values. The abundance pattern of this component is close to that of lambda Boo type stars. The abundances of light elements, except oxygen, in the atmosphere of the secondary (hotter) component are practically solar. The oxygen overabundance is 0.7 dex. The abundances of barium and two detected lanthanides are slightly supersolar. The abundances of two components are evidently different. The comparison of relative abundances with the condensation temperatures and ionization potentials of the elements confirms the difference of abundance patterns.

II.4. A large database of Cepheid spectra was created by Andrievsky and Korotin. Currently, it includes about 250 stars, and for some of them multiphase spectra are available. At present, this database is used to derive the NLTE barium abundance from all available spectra and then to construct the radial distribution of this element abundance in the Galactic disc. It should be noted that such an ambitious project is realized for the first time.

This underlines success results attained for **milestone 5.**

III. Nuclear data, fission and nucleosynthesis (ITEP Moscow)

III.1 The formation of heavy elements in neutron star mergers (NSM) is based on a rather long duration of the r-process and leads to an efficient production of the heavy r-elements, combined with an exhaustion of seed nuclei. The nucleosynthesis flow approaches rapidly the actinide region, where in addition to neutron-induced fission, delayed, and spontaneous fission contribute, all of them causing fission cycling. Fission products act again as r-process seeds, resulting essentially in elements with A>100. Therefore, the contribution of different fission types is very important for the nucleosynthesis of heavy and superheavy nuclei, especially spontaneous fission contributes during the cooling stage. Spontaneous fission lifetimes are extremly short and can stop the formation of long-lived superheavy nuclei (SHE) at the end of the r-process. Applying different models for spontaneous fission lifetimes, it was shown that formation of SHE depends strongly on regions of nuclei with very short s.f. lifetimes, whose sizes vary strongly for different models.

III.2 Beta-delayed fission together with neutron-induced and spontaneous fission is responsible for the suppression of superheavy elements yields both during the r-process and after neutron exhaustion. For beta-delayed fission new beta strength-function calculations are required. We showed that existing beta-delayed fission probabilities are probably overestimated due to incomplete beta-strength-functions involved in the calculations. To overcome the problem, a new approach based on the finite Fermi-systems theory, was applied.
The calculations are based mass and fission barrier predictions in the framework of the Extended Thomas-Fermi and Strutinsky Integral (ETFSI) approach. Probabilities for delayed fission and neutron emission were provided for an extended number of isotopes, supporting the above finding that in previous evaluations the probabilities of delayed processes were overestimated significantly. Applications of the new results to r-process calculations can change significantly both the r-process path as well as the yields of superheavy elements, but extended calculations of these nuclear data are needed, which is planned for 2012 with subsequent applications to r-process calculations.
Because of large uncertainties in spontaneous fission models, we evaluated more approaches than planned initially. Thus, the total amount of work increased, requiring additional calculations of the r-process with modifying spontaneous fission rates and beta-delayed probabilities. Both will be done during the 3d year. **(Milestone 3a is completed, the extension of 1b and applications will be performed during the 3d year. 3b is progressing according to the initial plan, but with an increased number of scenarios/sites, see below).**

IV. Core collapse supernovae theory, including NLTE-effects, and simulations of shock-breakout (ITEP Moscow)

IV.1 Yudin and Nadyozhin completed their work on the excluded-volume approximation (EVA). A general scheme of EVA as applied to a multicomponent system with an arbitrary degree of degeneracy has been developed. Such a scheme also allows to include some additional interactions between the components of the system (e.g. the Coulomb interaction). A specific form of the excluded-volume function for investigating supernova matter at sub-nuclear densities has been found from comparison with the hard-sphere model. The possibility of describing the phase transition to uniform nuclear matter is also considered.

This general approach to the EVA developed here can serve as a tool for investigating extreme states of matter. Different thermodynamically consistent models for the equation of state can be obtained by choosing different forms of the excluded-volume function υ_n and the corresponding additional interaction potential. Using this EVA method, one has a possibility to reproduce the results of the hard-sphere model in the Boltzmann limit (see M. Lopez de Haro, S. B. Yuste, and A. Santos, Lect. Not. Phys. 753, 183, 2008). This approach is apparently adequate for describing a multicomponent mixture of free nucleons and nuclei under NSE conditions for supernova matter at sub-nuclear densities.

It can be used not only to study the thermodynamic properties of matter but also to obtain detailed information about its chemical composition. This is a serious advantage of this approach over the popular mean-nucleus models. For example, nucleosynthesis problems can be solved by using only this type of equations of state. In addition, it has been shown that using this approach to the EVA, it is possible to obtain the phase transition to uniform nuclear matter and, hence, use this equation of state in hydrodynamic simulations of supernova explosions.

Nadyozhin and Yudin also continued their work on the neutrino-heat conduction theory (NHC) as generalized for a 2-D axially-symmetric case. The NHC theory was formulated by Imshennik & Nadyozhin (JETP, 63, 1548, 1972) as an approach for describing the neutrino-matter evolution in the neutrino-opaque domains of collapsing stars. It was formulated in 1-D and accounts only for pure absorption/emission processes. The way to include an arbitrary scattering processes as well was proposed in Yudin & Nadyozhin, Astronomy Letters,Vol. 34, No. 3, (2008). Now the NHC equations, which describe co-evolution of matter and neutrino field in the axially-symmetric case, are obtained (Yudin, PhD Theses, 2009; Nadyozhin and Yudin, France, Les Houches, 2011).

This 2-D case is very important for the exploration of core-collapse mechanisms of supernova explosions, which have rotation as an important ingredient. There are at least two such a mechanisms: the rotational one by V.S. Imshennik and magneto-rotational by G.S. Bisnovatyi-Kogan. In both of them the complicated underlying physics of explosion must be supplied with the proper neutrino transport calculations. The 2-D NHC approach is possibly the best way to do this because the solution of NHC equations is much simpler (without loss of accuracy in the opaque domains) than a straightforward solution of full transport equations for neutrino. As was demonstrated (Yudin, PhD Theses, 2009) the NHC applicability region occupies a considerable part of collapsing stellar core. In addition, the advantage of the NHC theory consists in the fact that in the framework of this approach the information about all neutrino-matter interactions (both absorption/emission and scattering processes) are “packed” in only three (because of Onsager’s principle) coefficients. These coefficients can be calculated offline and stored as a functions of thermodynamic parameters. For example, in the NSE case there are three such parameters: temperature T, density ρ and lepton fraction Y_e. The use of such tables makes it possible to significantly accelerate the hydrodynamical simulations of supernova explosions. All the above-listed reasons explain why the NHC theory should be used in modern computational explorations of supernova explosion problem.

IV. 2 As a part of the project the research of NLTE effects has been performed (Blinnikov and Baklanov). Additional modules have been written and embedded into the existing multigroup radiative hydrodynamics code STELLA kinetics (with PhD student Potashov). The new modules take into account NLTE effects while the old STELLA version was calculating the evolution of an SN burst after the explosion in LTE approximation for radiation hydrodynamics.
The conditions leading to the breakdown of LTE approximation were explored and it was shown that under these conditions the rates of collisional ionization are negligible in comparison to the rates of photoionization. Taking into account the obtained estimates, we conclude that the conditions in the SN envelope allow us to neglect the collisional processes and to consider only the radiative ones. Given the fact that the radiative processes are dominating, we can use an approach similar to the formulas applied for planetary nebulae, as suggested by Lucy (1999) for the problems of stellar mass-loss.
It is shown that the new equation of state, based on Lucy's approximation for NLTE, shifts the balance of ion concentrations to a higher degree of ionization. The recombination of ions in the envelope of a supernova is efficiently constrained and slowed down by radiation, even when the local gas temperature is low. Computations of the ion structure in a SN envelope were compared to the results obtained by our colleagues at MPA Garching. The agreement between the results of the calculations of the two groups is good.
Preliminary calculations for SNe Ia based on the model W7 have been carried out. The main effect of NLTE appears at later stages of the light curves evolution, before the transition to the nebular stage. Under NLTE conditions the envelope matter is ionized more strongly than in LTE. This increases the opacity of the envelope and leads to a more efficient conversion of energy of the radioactive decays of ^{56}Ni and ^{56}Co into the observable luminosity. This, in turn, leads to an increase in luminosity in the optical range and affects significantly the light curves of SNe. In 2012, we plan to get final results from the calculations of SNe Ia, as well as self-consistent investigations of the radiation-hydrodynamics evolution of an Sne IIP, taking into account the NLTE effects.

IV.3 Potashov M.Sh., Blinnikov S.I., and Baklanov P.V. have calculated supernova spectra taking into account time-dependent NLTE processes within a Sobolev approximation. Multiplet line coupling beyond the Sobolev approach is taken care of. The STELLA radiation-hydrodynamics package produces all self-consistent hydrodynamics and thermodynamics parameters, and photospheric intensities in LTE. After that a new NLTE code calculates rate equations and transport equations beginning with the previously obtained data and Saha- or Lucy-type initial conditions. The rate equations include all relevant bb, ff, bf, fb (bound-bound, free-free, bound-free, free-bound) processes and there are no LTE and steady-state assumptions.
The transport equations are simplified by the Sobolev approximation. As a last step one may obtain spectral line profiles. The results of our calculations show the importance of the time-dependent effects in spectral evolution of classical type IIP supernovae.

IV.4 Taking into account peculiarities, which are important for the correct numerical modeling of shock breakouts in supernova, a number of models for different supernova types have been constructed, based on multigroup radiation transfer coupled to hydrodynamics (Tolstov and Blinnikov). **Thus milestone 7b was almost completed.** The following features have been included in the models:
(i) A new algorithm RADA, designed for modeling photon transfer at extremely-relativistic motions of matter, is merged with our older code STELLA.
(ii) Algorithms for conversion of radiation into the observer's frame of reference for one- and two-dimensional calculations of the light curves and spectra of supernovae at the epoch of shock breakout are developed.
(iii) Analytic tests of the applicability of radiation transfer equations is performed in the light scattering which is utilized in the numerical package STELLA. It includes the influence of

photon scattering on electrons, of the thermalization depth and of special relativity in transfer equation.
Elaborate numerical simulations of supernova shock breakouts can be used for evaluating and interpreting the detection of supernova explosions in current and planned space experiments, such as SWIFT, MAXI, EXISTS, etc. The results of these experiments in turn can help to answer a number of important questions in the theory of stellar evolution and cosmology. The plan for combinig the raditiation hydro code STELLA with the relativstic transport code RADA is completed 100%. However, STELLA may be used only for mildly relativistic flows. To continue and extend the work, A.Tolstov is advancing RADA to combine it with a fully relativistic hydrodynamic code for large Lorentz factors. This should be accomplish in 2012.

V. Burning flame front investigation in SNIa explosions (ITEP Moscow)

V.1 A simple model that exhibits dynamical flame properties in one dimension (Glazyrin, Blinnikov) has been worked out. This is investigated analytically and numerically. The results are applicable to problems of flame propagation in Type Ia supernovae.

V.2 A numerical study is performed to follow the growth of small perturbations of the combustion front in a supernova, taking into account the Landau-Darrieus instability. Numerical solutions are obtained which allow the analysis of the growth of perturbations and their evolution (as well as their impact on the surrounding flow) in the flame of a supernova.

The activities were in full accordance of the initial project. Due to more detailed and some alternative approaches than initially planned, even more investigations were undertaken. This also led to more presentations of the results than expected. Ukrainian and Russian scientists attended 11 scientific conferences instead of 6 which were planned originally.

Some preliminary results of the project tasks were presented at

- The 8th Russbach Workshop on nuclear astrophysics. Russbach, Austria, 14-18 March, 2011.
- Conference "*From Nuclei to White Dwarfs and Neutron Stars*", France, Les Houches, April 3-9, 2011
- Int. Conf. "Assembling the puzzle of the Milky Way", Grand Bornand, France, 18.04-22.04 2011
- JENAM-2011, Symposium S5 Physics of stars, Saint-Petersburg, Russia, 5-6 July, 2011.
- Conference "Physics of Neutron Stars" Saint-Petersburg, Russia, July 11-15, 2011
- Helmholz International Summer School "Nuclear theory and astrophysical applications". BLTP, JINR. Russia, Dubna, July 24- August 2, 2011
- 11th International Gamow Summer School "Astronomy and beyond: astrophysics, cosmology and gravitation, cosmomicrophysics, radioastronomy and astrobiology. August 23-28, 2011. Odessa, Ukraine
- Workshop, supported by SCOPES "Heavy elements in galactic chemical evolution and NLTE effects", August, 30 — September, 2, 2011, Odessa, Ukraine.
- Workshop, supported by SCOPES "Nucleosynthesis and SN physics". 5 september, 2011, IA RAS, Moscow
- International Conference on the Chemistry and Physics of the Transactinide Elements: TAN'11. 05-11 September 2011, Sochi (Russia).
- International conference "KOLOS – 2011: Astronomy and other Natural Sciences in the Life of Society", December, 1 – 3, 2011, Vyhorlat Observatory, Snina, Slovakia

VI. Core collapse supernovae, multi-D radiation transport, long-term neutrino wind simulations, nuclear reaction and equation of state input, as well as nucleosynthesis (Basel)

VI.1 Nuclear reaction rates have been calculated with the aid of the non-Smoker code (Rauscher & Thielemann 2000, and updates), for: neutron-induced fission calculations (Panov et al. 2011ab), many neutron-capture reactions (Rauscher jointly with the nToF-collaboration) as well as charged-particle reactions far from stability (Dillmann et al. 2011). Nuclear equation of state developments and tests for core-collapse supernovae have been carried out by Hempel et al. (2011ab) and Fischer et al. (2011ab). This relates all to **milestone 1**.

VI.2 Extended efforts were undertaken in 1D and multi-D radiation transport, applied to core-collapse supernova calculations (Fischer et al. 2011cd, Lentz et al. 2011, Pang et al. 2011), the multi-D magneto-hydrodynamics (MHD) code FISH was developed by R. Käppeli (Käppeli et al. 2011), making use of the isotropic diffusion source approximation (ISDSA) for neutrino transport, and succesful applications were performed for core-collapse supernobae with rotation and magnetic fields (Winteler et al. 2011, (**milestone 2)**.

VI.3 Phenomenological tests in r-process, νp-process, and p-process parameter studies of the neutrino wind of core-collapse supernovae have been performed with extended constraints from nuclear physics/reaction input (Arcones and Bertsch 2011, Arcones (et al.) 2011a-d, Thielemann et al. 2011, Langanke et al. 2011) (**milestone 3a**). Attempts to analyze this in realistic models were undertaken by Arcones & Janka (2011), Arcones & Montes (2011), Petermann et al. (2011) and Arcones (2011) (**milestone 3b**).

VI.4 A very general review of the role of massive stars and their supernovae in the chemical evolution of galaxies was presented, pointing out especially the highly uncertain understanding of nuclei between the Fe-group and the A=130 r-process peak (Thielemann et al. 2011, Nishimura et al. 2011) (**milestone 6**).

VI.5 Stellar evolution studies analyzing nuclear input sensitivities (e.g. $^{12}C+^{12}C$) were undertaken (Bennett et al. 2011), The effect of rotation and resulting primordial ^{14}N and ^{22}Ne, plus the influence on s-process abundances at low metallicities was investigated by Frischknecht et al. (2011) (**milestone 3b**).

VI.6 The progenitor evolution of type Ia supernovae in order to understand the seed composition of accreted and H/He-burned matter was analyzed by M. Pignatari (in preparation) (**milestone 7b**)

VII. Stellar models, including hydrodynamical processes, impact on stellar properties and nucleosynthesis, consequences for chemical evolution (Geneva)

VII.1 We study the impact of rotation, diffusion, gravity waves, and thermohaline instability on the stellar structure and evolution for stars over a large domain in both stellar mass and metallicity (Ekström et al. 2012, Lagarde et al. 2011, Lagarde et al. Submitted to A&A). The latter provides grids of models including these non-standard processes and the various predictions are tested using different constraints (surface abundances, asteroseismology, chemical evolution) for stars of various masses at different evolutionary stages **(milestones 3b, 6).**

VII.2 The resulting effect of massive low metallicity stars with rotation on the chemical evolution of galaxies was extensively analyzed by Chiappini et al. (2011) (milestone 3b, 6). The predictions for the yields of light elements of our new stellar models including rotation-induced mixing and thermohaline instability were also tested againts Galactic evolution. In particular, the resulting evolution of the light elements D, He and He was compared with their primordial values inferred from the Wilkinson Microwave Anisotropy Probe data and with the abundances derived from observations of different Galactic regions. We showed that Galactic chemical evolution models computed with stellar yields including thermohaline mixing and rotation fit better observations of ^{3}He and ^{4}He in the Galaxy than models computed with standard stellar yields. In particular the inclusion of thermohaline mixing in stellar models provides a solution to the long-standing "3 He problem" on a Galactic scale. Stellar models including rotation-induced mixing and thermohaline instability reproduce also the observations of D and 4 He. (Lagarde et al., submitted to A&A).

VII.3 We investigate the chemical and dynamical evolution of globular clusters and the impact on the halo stellar population. We examine various implications from a dynamical and chemical model of globular clusters, which successfully reproduces the observed abundance patterns and the multiple populations of stars in these systems assuming chemical enrichment from fast rotating massive stars. Typically, we find that the initial masses of globular clusters must be ~8-10 times (or up to 25 times, if second generation stars also escape from globular clusters) larger than the present-day stellar mass. The present-day Galactic globular clusters population must then have contributed to approximately 5-8% (10-20%) of the low-mass stars in the Galactic halo. We also show that the detection of second generation stars in the Galactic halo, recently announced by different groups, provides a new constraint on the GC initial mass function. These observations appear to rule out a power-law GCIMF, whereas they are compatible with a log-normal one (Charbonnel & Montmerle 2011). Finally, the high initial masses also imply that globular clusters must have emitted a large amount of ionising photons in the early Universe. Our results reopen the question on the initial mass function of globular clusters, and reinforce earlier conclusions that old globular clusters could have represented a significant contribution to reionise the inter-galactic medium at high redshift (Schaerer & Charbonnel 2011). These theoretical studies are complemented by observational works with VLT that help tracing the evolution of globular clusters through the chemical composition of their stellar populations (Lind, Charbonnel et al. 2011)(**milestone 6**).

Highlights of the Collaboration:

Major events in 2011 were joint Ukrainian/Russian/Swiss workshops in Odessa and Moscow:
(1) About 30 scientists from the Ukraine, Russia, Switzerland, and Germany attended the Workshop in Odessa. on "Heavy elements in galactic chemical evolution and NLTE effects". In the framework of the workshop, after two days of work, the round table with SNF-grant participants and scientists from all participating institutions was held. In the extended discussion Almudena Arcones, Sylvia Ekström, Karl-Ludwig Kratz, Tamara Mishenina, Lyudmila Mashonkina, Igor Panov, Marco Pignatari and Friedrich-Karl Thielemann pointed out the work progress and emphasized the importance of the discussion, in which all the project members took part. It was noted that on the way to developing more realistic, physical scenarions of stellar evolution, nucleosynthesis and SN explosions, progress was visible in all related aspects - observations, interpretation of chemical evolution data, nucleosynthesis predictions in stellar winds and explosions, as well as hydrodynamics, magnetohydrodynamics, and radiation/neutrino transport in astrophysical simulations of supernovae..
(2) In Moscow in a shorter workshop addressed the following questions: further r-process calculations with different sf-rates (Korneev), results of preliminary calculations of supernova spectra, taking into account time-dependent NLTE processes for multiply charged ions in the

Sobolev approximation (Potashov), problems in numerical simulations of multigroup relativistic transfer for supernova shock breakout (Tolstov), possibility of neutrino nucleosynthesis in helium and carbon shells of core-collapse supernovae (Nadyozhin), and the excluded volume approximation for the equation of state of supernova matter (Yudin).

Both events, their programs and presentation slides can be found on the website:
http://dau.itep.ru/sn/collaboration

Talks presented at conferences, schools and workshops:

participants from Ukraine and Russia:
1. Baklanov P., Blinnikov S. ``NLTE effects in the supernova envelopes''
Workshop 'Heavy elements in galactic chemical evolution and NLTE effects', Odessa 01.09.11
2. M. Potashov «Calculations of supernova spectra, taking into account time-dependent NLTE processes for multiply charged ions in the Sobolev approximation»
3. A.Tolstov «Simulations of multigroup relativistic transfer for supernova shock breakout»
Workshop on Nuclesynthesis and supernova physics, Moscow, INASAN, 05.09.11
4. Blinnikov S., "Supernovae as direct distance indicators in cosmology". Physikalisches Kolloquium im Physikalischen Institut, Bonn Universitaet, Bonn 2.12.2011.
5. Blinnikov S., Baklanov P., Potashov M., Tolstov A., Sorokina E. ``Supernovae in cosmology''.
Conference 'High Energy Astrophysics' HEA2011, IKI (Space Research Institute) Moscow 14.12.11
6. Glazyrin S., Blinnikov S. ``Investigation of a burning wave in a supernova of type Ia''
Conference 'High Energy Astrophysics' HEA2011, IKI (Space Research Institute) Moscow 14.12.11
7. D.K. Nadyozhin, A.V. Yudin, "The Neutron Heat Conduction Theory in Collapsing Stellar Cores" Conference "*From Nuclei to White Dwarfs and Neutron Stars*" , France, Les Houches , April 3-9, 2011
8. D.K. Nadyozhin, A.V. Yudin "Principal Physical Effects in Collapsing Stellar Cores ", Conference "*From Nuclei to White Dwarfs and Neutron Stars*" , France, Les Houches , April 3-9, 2011
http://www.icranet.org/index.php?option=com_content&task=view&id=559
9. D.K. Nadyozhin, lecture **"**Neutrino-induced nucleosynthesis in supernovae"
Helmholtz International Summer School "*Nuclear Theory and Astrophysical Applications*". Joint Institute for nuclear research, Dubna, Russia, July 24 – August 2, 2011
http://theor.jinr.ru/~ntaa/11/
10. I.V. Panov. Nucleosynthesis of heavy, very heavy, superheavy? nuclei in the r-process, Workshop The Origin of the Elements: A Modern Perspective. ECT* Trento, Italy,
16-20 May, 2011
11. I.Yu. Korneev and I.V. Panov
What kind of fission is more important in the r-process?
Conference "Physics of Neutron Stars" Saint-Petersburg, Russia, on July 11-15, 2011
12. Igor Panov. Fission rates and transactinide formation in the r-process.

Workshop "Heavy elements in galactic chemical evolution and NLTE effects"
Organized by ITEP, University of Basel, Odessa NU, Observatory of Geneva
August, 30 – September, 2, 2011, Odessa, Ukraine

13. Igor Panov, Reaction rates and formation of superheavy elements in NSM, International Conference on the Chemistry and Physics of the Transactinide Elements: TAN'11. 05-11 September 2011, Sochi, Russia
14. Mishenina T.V. Chemical composition of stars in the disk substructures of the Galaxy. International conference "Assembling the puzzle of the Milky Way", Grand Bornand (France), 18.04-22.04 2011.
15. Mishenina T.V., Korotin S.A., Soubiran C., Gorbaneva T. I., Basak N.Yu.. Elemental abundances in FGK dwarfs of the galactic disk. JENAM-2011, St-Petersburg, Russia.
16. Andrievsky S., Korotin S. NLTE abundance of Sr and Ba in the early Galaxy. Workshop, supported by SCOPES "Heavy elements in galactic chemical evolution and NLTE effects", August, 30 — September, 2, 2011, Odessa, Ukraine
17. Mishenina T. Chemical composition of stars in the substructures of the Galaxy. Workshop, supported by SCOPES "Heavy elements in galactic chemical evolution and NLTE effects", August, 30 — September, 2, 2011, Odessa, Ukraine
18. Yushchenko V.A. HD 25354: has or not the radioactive elements? Workshop, supported by SCOPES "Heavy elements in galactic chemical evolution and NLTE effects", August, 30 — September, 2, 2011, Odessa, Ukraine
19. Chekhonadskih F: Odessa database of atmospheric parameters and chemical composition of stars. Workshop, supported by SCOPES "Heavy elements in galactic chemical evolution and NLTE effects", August, 30 — September, 2, 2011, Odessa, Ukraine
20. Yushchenko V.A. The chemical composition of MCP star HD 25354. 11-th International Gamow Summer School "Astronomy and beyond: astrophysics, cosmology and gravitation, cosmomicrophysics, radioastronomy and astrobiology. August 23-28, 2011. Odessa, Ukraine.
21. Chekhonadskih F: "Intrinsic color indexes and absolute stellar magnitudes of FGK supergiants". International conference "KOLOS – 2011: Astronomy and other Natural Sciences in the Life of Society", December, 1 – 3, 2011, Vyhorlat Observatory, Snina, Slovakia.
22. L. Mashonkina, Observations of heavy elements in very metal-poor stars. The 8th Russbach Workshop on nuclear astrophysics. Russbach, Austria, 14-18 March, 2011.
23. L. Mashonkina, Non-LTE line formation for Pb I and Th II in cool stars. Workshop supported by the SCOPES Program "Heavy elements in galactic chemical evolution and NLTE effects». August 30-September 2, 2011, Odessa, Ukraine, Organized by ITEP, University of Basel, Odessa NU, Observatory of Geneva.
24. T. Sitnova, Signatures of the r-process in heavy element abundances of a halo star HD 29907. Workshop supported by the SCOPES Program "Heavy elements in galactic chemical evolution and NLTE effects». August 30-September 2, 2011, Odessa, Ukraine
25. T. Sitnova, The r- and s-process contribution to heavy elements in a halo star HD 29907, JENAM-2011, Symposium S5 Physics of stars, Saint-Petersburg, Russia, 5-6 July, 2011.

participants from Switzerland:

A. Arcones: Nucleosynthesis beyond iron in core-collapse supernovae, EMMI Physics Days, Darmstadt, Germany (2011)

A. Arcones: Impact of nuclear physics input on the r-process, Thermonuclear Reaction Rates for Astrophysics Applications, Athens, Greece (2011)

A. Arcones: Core-collapse supernovae and r-process, The Chemical Evolution of Galaxies, Basel, Switzerland (2011)

C. Charbonnel: Transport processes and nucleosynthesis in stars: open questions and perspectives, workshop on Red Giant Stars, Montpellier, France (2011)

C. Charbonnel:Globular clusters - Multiple populations, early evolution, and contribution to the Galactic halo, Stellar Clusters and Associtions – A RIA workshop on Gaia, Granada, Spain (2011)
C. Charbonnel: The turbulent infancy of globular clusters: Multiple populations, multiple consequences, Invited Colloquium at the Osservatorio Astronomico di Roma, Roma, Italy (2011)
C. Charbonnel: The turbulent infancy of globular clusters: Multiple populations, multiple consequences, The Chemical Evolution of Galaxies, Basel, Switzerland (2011)
C. Charbonnel: Effecs of rotation and thermohaline mixing on the structure and chemical properties of red giant stars, Bcool meeting, Toulouse, France (2011)
C. Charbonnel: The turbulent infancy of globular clusters: Multiple populations, multiple consequences, Invited Colloquium IRAP, CNRS, Toulouse, France (2012)
C. Charbonnel: Lithium processing in stars: Diagnosis for stellar structure and evolution, IAP International workshop on Lithium in the Cosmos, Paris, France (2012)
U. Frischknecht: Sr, Y and Zr from rotation induced s process in massive stars, Nucleosynthesis beyond iron and the lighter element primary process (LEPP), Darmstadt, Germany (2011)
U. Frischknecht: s-Process in massive rotating stars, The Chemical Evolution of Galaxies, Basel, Switzerland (2011)
M. Hempel: New Equations of State in Simulations of Core-Collapse Supernovae, Gravitational Waves and Electromagnetic Radiation from Compact Stars, Catania, Italy (2011)
M. Hempel: New equations of state in simulations of core-collapse supernova, Nuclear Fragmentation 2011, Kemer, Turkey (2011)
M. Hempel: Light clusters and new equations of state in simulations of core-collapse supernovae, Clusters in Nuclei and Nuclear Matter: Nuclear Structure, Heavy Ion Collisions, and Astrophysics, Trento, Italy (2011)
M. Hempel: Exotic nuclei and the equation of state in core-collapse supernovae, The shell model, Trento, Italy (2011)
M. Liebendörfer: Neutrino emission in core collapse supernovae, Neutrinoemission in core-collapse supernovae, The Origin of the Elements: A Modern Perspective, Trento, Italy (2011)
M. Liebendörfer: 3D Supernova Models, Microphysics in Computational Relativistic Astrophysics, Waterloo, Canada (2011)
M. Liebendörfer: Microphysics of the Supernova Core, HAnSE: HAmburg neutrinos from Supernova Explosions, Hamburg, Germany (2011)
M. Liebendörfer: Core-collapse supernovae and their explosion mechanisms, The Chemical Evolution of Galaxies, Basel, Switzerland (2011)
N. Nishimura: New Supernova Scenarios for r-process Nucleosynthesis, Heavy elements in galactic chemical evolution and NLTE effects, Odessa, Ukraine (2011)
N. Nishimura: Heavy Element Nucleosynthesis in Supernova triggered by a quark-hadron phase transition, Supernova Conference 2011, Kyoto, Japan (2011)
Pignatari M.: Production of copper, gallium and germanium in massive stars, The Origin of the Elements: A Modern Perspective, ECT* Trento, Italy (2011)
Pignatari M.: Production of Mn in stars, SCOPES workshop: Heavy elements in galactic chemical evolution and NLTE effects, Odessa, Ukraine (2011)
Pignatari M.: Slow neutron capture process in massive stars, 8th Russbach Workshop on Nuclear Astrophysics, Russbach, Austria (2011)
T. Rauscher: Astrophysical reaction rates for proton- and neutron-rich nucleosynthesis (and connections to experiments), The Origin of the Elements: A Modern Perspective, Trento, Italy (2011)
T. Rauscher: Origin of the p-Nuclides and Relevant Astrophysical Reaction Rates, The p-Process: Present Status and Outlook, Istanbul, Turkey (2011)
T. Rauscher: Complications in Determining Stellar Reaction Rates for Explosive Nucleosynthesis, 10th Int. Symp. on Origin of Matter and Evolution of the Galaxies (OMEG11), Osaka, Japan (2011)

T. Rauscher: Reaction Rates between the Driplines for Astrophysics, The shell evolution and the role of correlations in very neutron rich nuclei, Trento, Italy (2011)
F.-K. Thielemann: 70 Years of exotic matter/nuclei: Karl-Ludwig Kratz, from Pn to Sn, 8th Russbach Workshop on Nuclear Astrophysics Russbach, Austria (2011)
F.-K. Thielemann: Nuclear Burning in Accreting Compact Objects, Mapping Neutron Stars with Type I X-Ray Bursts, Bern, Switzerland (2011)
F.-K. Thielemann: Summary Talk, The Origin of the Elements: A Modern Perspective, Trento, Italy (2011)
Thielemann F.-K.: Did Nature produce superheavy elements? TAN 11, Physics and Chemistry of Transactinide Nuclei, Sochi, Russia (2011)
Thielemann F.-K.: Nucleosynthesis in Astrophysical Explosions and the Origin of Heavy Elements, Advanced Topics in Astrophysics Llafranc, Spain (2011)
Thielemann F.-K.: Radioactivity and Nucleosynthesis as Probes of (core collapse) Explosion Models, Explosive Ideas about Massive Stars - from Observations to Modeling, Stockholm, Sweden (2011)
F.-K. Thielemann: How many processes contribute to the heavy element abundances in the Fe-group and beyond and what are/could be their astrophysical sites? Heavy elements in galactic chemical evolution and NLTE effects, Odessa, Ukraine (2011)

Web pages prepared by grant members:

http://dau.itep.ru/sn/lctheory - Tools for Supernova Light Curve Catalogue
http://dau.itep.ru/sn/snviewobs - The Catalogue of the Supernova Light Curves
http://dau.itep.ru/sn/snview - The Catalogue of the Supernova explosion models
http://dau.itep.ru/sn/snatomicdata - The list of atomic lines with wavelengths in the range from 0.1 E to 100000 A. It contains 152651 atomic transitions.

2.2 Is the co-operation progressing satisfactorily according to expectations with regard to collaboration?

As seen from the details given above, it can be seen that all groups are very active in their related and overlapping research fields from nuclear input over stellar modeling and abundance observations in (old) stars, to their interpretation in chemical evolution of galaxies. Also a number of joint investigations of at least two of the participating groups have taken place or are in progress.
Seven meetings where members of the Swiss groups and the groups from Eastern Europe could jointly attend, have increased the overlap and joint planning strongly. In the list of publications given at the end of the report, one can recognize that a true collaboration has started. There are (in 2011) in total 8 joint publications, which include members of more than one of the participating research groups. One also finds in total 8 publications of our Eastern European Partners with collaborators from the West, underlining that our partners have an international standing, going beyond the collaboration with the Swiss groups.

2.3 Please list the involved individuals:

Name	Country	Age	Sex	Remarks
Andrievsky Sergei	Ukraine	50	M	Prof
Chekhonadskhih Fedor	Ukraine	27	M	PhD student
Korotin Sergei	Ukraine	49	M	PhD
Mishenina Tamara	Ukraine	61	F	Prof
Yushchenko Vladimir	Ukraine	25	M	PhD student
Baklanov Petr	Russia	32	M	Master
Blinnikov Sergey	Russia	63	M	Prof
Glazyrin Semen	Russia	25	M	Bachelor
Korneev Ivan	Russia	28	M	Master
Mashonkina Lyudmila	Russia	59	F	Prof
Nadyozhin Dmitriy	Russia	74	M	Prof
Panov Igor	Russia	60	M	PhD
Tolstov Aleksei	Russia	33	M	PhD
Sitnova Tatiana	Russia	25	F	Bachelor
Yudin Andrey	Russia	33	M	PhD
Corinne Charbonnel	Switzerland	46	F	Prof.
Daniel Schaerer	Switzerland	47	M	Prof.
Cristina Chiappini	Switzerland	43	F	Prof.
Nadege Lagarde	Switzerland	29	F	PhD student
Georges Meynet	Switzerland	53	M	Prof.
Sylvia Eckström	Switzerland	45	F	postdoc
Cyril Georgy	Switzerland	29	M	PhD student
Friedrich-K. Thielemann	Switzerland	60	M	Prof.
Matthias Liebendörfer	Switzerland	46	M	Prof.
Thomas Rauscher	Switzerland	46	M	Lecturer
Marco Pignatari	Switzerland	31	M	Postdoc
Almudena Arcones	Switzerland	33	F	Postdoc
Matthias Hempel	Switzerland	33	M	Postdoc
Nobuya Nishimura	Switzerland	31	M	Postdoc
Urs Frischknecht	Switzerland	32	M	PhD student
Roger Käppeli	Switzerland	29	M	PhD student
Albino Perego	Switzerland	29	M	PhD student
Christian Winteler	Switzerland	30	M	PhD student

3. Practical issues

3.1 Did you encounter any major problems (e.g. telecommunication, transfer of goods, taxation, customs)? If yes, please specify the problems and describe how you solved them.

3.2 How did you transfer the funds to the project partners in Eastern Europe?

The Russian team leader used a CHF-account at UBS-Bank, Basel.
The money was sent by 2 installments to the account, as in previous years. (SCOPES program 2005-2008, grant No. IB7320-110996**)**
The Ukrainian team leader opened a special CHF-account at UKRSIBBANK Bank in Odessa for the transfer from SNF. The money, according to the rules of SNF (Guidelines for the Administration of Grants for Joint Research Projects, item 4.) was sent by 2 installments to the account.

3.3 Are there important developments/changes in the scientific landscape of the involved partner countries?

For our research project: Postgraduate student Sitnova (Institute of Astronomy) replaced Velichko (maternal leave).

4. Annexes

Include any documents (publications, proceedings, etc.) which you consider to be of relevance.

Publications (published, submitted, in press, in final stage of preparation):

Ukrainian/Russian publications in regular style (with other western – non-Scopes – teams underlined), Swiss publcations in italic, joint publications in bold face

1) A.V. Yudin, Excluded-Volume Approximation for Supernova Matter, Astronomy Letters 37 (2011), 576

2) M. I. Krivoruchenko, D. K. Nadyozhin, T. L. Rasinkova, Yu. A. Simonov, M. A. Trusov, A. V. Yudin, Nuclear Matter At High Density: Phase Transitions, Multiquark States, and Supernova Outbursts", Physics of Atomic Nuclei 74 (2011), 371

3) Blinnikov, S.I., Panov, I.V., Rudzsky, M.A., Sumiyoshi, K., The equation of state and composition of hot, dense matter in core-collapse supernovae, Astronomy and Astrophysics 535 (2011), A37

4) Hempel, M., Schaffner-Bielich, J., Typel, S., Röpke, G., Light clusters in nuclear matter. Excluded volume versus quantum many-body approaches, Phys. Rev. C 84 (2011), 055804

5) Hempel, M., Fischer, T., Schaffner-Bielich, J., Liebendörfer, M., New equations of state in core-collapse supernova simulations, arXiv:1108.0848 (2011), Ap.J., submitted

6) Fischer, T., Blaschke, D., Hempel, M., et al.: Core collapse supernovae in the QCD phase diagram, arXiv:1103.3004 (2011), CPOD2010 conference proceedings

7) Fischer, T., Sagert, I., Pagliara, G., Hempel, M., Schaffner-Bielich, J., Rauscher, T., Thielemann, F.-K., Käppeli, R., Martinez-Pinedo, G., Liebendörfer, M.: Core-collapse Supernova Explosions Triggered by a Quark-Hadron Phase Transition During the Early Post-bounce Phase Ap. J. Suppl. 194 (2011), 39

8) Käppeli, R., Whitehouse, S. C., Scheidegger, S., Pen, U.-L., Liebendörfer, M.: FISH, A Three-dimensional Parallel Magnetohydrodynamics Code for Astrophysical Applications, Ap. J. Suppl. 195 (2011), 20

9) Lentz, E.J., Mezzacappa, A., Bronson Messer, O.E., Liebendörfer, M., Hix, W.R., Bruenn, S.W., On the Requirements for Realistic Modeling of Neutrino Transport in Simulations of Core-Collapse Supernovae, arXiv:1112.3595 (2011), Ap.J., in press

10) Fischer, T., Martinez-Pinedo, G., Hempel, M., Liebendörfer, M., Neutrino spectra evolution during proto-neutron star deleptonization, arXiv:1112.3842 (2011), Phys. Rev.D, in press

11) Fischer, T., Liebendörfer, M., Thielemann, F.-K., Long-term evolution of massive star explosions arXiv:1112.5528 (2011), Proc. Hanse 11, in press

12) Pang, B., Pen, U.-L., Matzner, C. D., Green, S. R., Liebendörfer, M., Numerical parameter survey of non-radiative black hole accretion: flow structure and variability of the rotation measure, Mon. Not. Roy. Astron. Soc. 415 (2011), 1228

13) Bonazzola, S., Vasset, N., Solving the transport equation by the use of 6D spectral methods in spherical geometry, arXiv:1104.5330 (2011), J. Comp. Phys., submitted

14) Kosenko, D., Blinnikov, S.I., Vink, J., Modeling supernova remnants: effects of diffusive cosmic-ray acceleration on the evolution and application to observations, Astronomy and Astrophysics 532 (2011), A114

15) N. Tominaga, T. Morokuma, S. Blinnikov, P. Baklanov, E. Sorokina, K. Nomoto, Shock Breakout in Type II Plateau Supernovae: Prospects for High-Redshift Supernova Surveys, Ap. J. Suppl. 193 (2011), 20

16) T. Moriya, N. Tominaga, S.I. Blinnikov, P.V. Baklanov, E.I. Sorokina, Supernovae from red supergiants with extensive mass loss, Monthly Notices of the Royal Astronomical Society 415 (2011), 199

17) Blinnikov S.I., Tolstov A.G., Multigroup radiative transfer in supernova shock breakout models, Astronomy Letters 37 (2011), 194

18) S.I. Glazyrin and P.V. Sasorov, Simple model of propagating flame pulsations, Monthly Notices of the Royal Astronomical Society 416 (2011), 2090

19) I.V. Panov, I.Yu. Korneev, T. Rauscher, F-K. Thielemann, Neutron-induced reaction rates for the r-process, Izv. RAN, ser. Phys. 75 (2011) 520 (Bulletin of the Russian Academy of Sciences)

20) I.V. Panov, I.Yu. Korneev, T. Rauscher, F-K. Thielemann, r-process reaction rates for the actinides and beyond, Proc. Seminar on Fission. Gent, Belgium, eds C. Wagemans, J. Wagemans and P.D'hondt, World Scientific Publishing Co., Singapore, p.255 (2011)

21) I.V. Panov, I. Yu. Korneev, Yu.Lutostansky, F.-K. Thielemann, Probabilities of beta-delayed processes for nuclei involved in the r-process, Physics of Atomic Nuclei (2011), in preparation

22) I. Petermann, G. Martinez-Pinedo, K. Langanke, F.-K. Thielemann, I.V. Panov, Did Nature produce superheavy nuclei? European Journal of Physics E (2011), in preparation

23) F. Belloni, .., Rauscher, T., .. et al.: Neutron-induced fission cross-section of ^{233}U in the energy range 0.5 < En < 20 MeV, Eur. Phys. J. A 47 (2011), 2

24) M. Calviani, .. Rauscher, T., .., et al. (nToF): Fission Cross-section Measurements of ^{233}U, ^{245}Cm and $^{241,243}Am$ at the CERN nTOF Facility, J. Kor. Phys. Soc. 59 (2011), 1912

25) D. Cano-Ott, .., Rauscher, T., .. et al. (nToF): Neutron Capture Measurements on Minor Actinides at the nTOF Facility at CERN: Past, Present and Future, J. Kor. Phys. Soc. 59 (2011), 1809

26) P. Milazzo, .., Rauscher, T. ..et al. (nToF): Neutron-induced fission cross section of ^{233}U in the energy range 0.5 < En < 20 MeV, Eur. Phys. J. A 47 (2011), 2

27) Tarro, D.,.., Rauscher, T. et al. (nToF): Measurements of high-energy neutron-induced fission of nat Pb and ^{209}Bi, Eur. J. Phys. Conf. Ser. 8 (2010), 07009

28) Calviano, M.,.., Rauscher, T. et al. (nToF): The neutron-induced fission cross-section of ^{245}Cm: new results from nTOF, Phys. Rev. C, submitted

Dillmann, I., Coquard, L., Domingo-Pardo, C., .., Rauscher, T., Thielemann, F.-K.: Cross sections for proton-induced reactions on Pd isotopes at energies relevant for the γ-process, Phys. Rev. C 84 (2011), 015802

29) Arcones, A., Bertsch, G.F.: Nuclear correlations and the r-process, arXiv:1111.4923 (2011), Phys. Rev. Lett, submitted

30) Thielemann, F.-K. Arcones, A.; Käppeli, R.; Liebendörfer, M.; Rauscher, T.; Winteler, C. Fröhlich, C.; Dillmann, I.; Fischer, T.; Martinez-Pinedo, G.; Langanke, K.; Farouqi, K.; Kratz, K.-L.; Panov, I.; Korneev, I. K. , What are the astrophysical sites for the r-process and the production of heavy elements? Progress in Particle and Nuclear Physics 66 (2011), 346

31) Langanke, K., Martınez-Pinedo, G., Petermann, I., Thielemann, F. K.: Nuclear quests for supernova dynamics and nucleosynthesis, Progr. Part. Nucl. Phys. 66 (2011), 319

32) I.V. Panov, I.Yu. Korneev, Contribution of fission to heavy-element nucleosynthesis in an astrophysical r-process, Astronomy Letters 37 (2011), 864

33) Arcones, A., Janka, H.-T.: Nucleosynthesis-relevant conditions in neutrino-driven supernova outflows. II. The reverse shock in two-dimensional simulations, A&A 526 (2011), A160

34) Arcones, A., Montes, F.: Production of Light-element Primary Process Nuclei in Neutrino-driven Winds, Ap. J. , 731 (2011), 5

35) Arcones, A., Martinez-Pinedo, G.: Dynamical r-process studies within the neutrino-driven wind scenario and its sensitivity to the nuclear physics input, Phys. Rev. C , 83 (2011), 045809

36) Arcones, A.: Explosive nucleosynthesis in core-collapse supernovae, J. Phys. Conf. Ser. 312 (2011), 042005

37) Nishimura, N., Fischer, T., Thielemann, F.-K., et al.: Nucleosynthesis in core-collapse supernova explosions triggered by a quark-hadron phase transition, arXiv:1112.5684 (2011), Ap., J., submitted

38)) Andrievsky, S. M., Spite, F., Korotin, S. A., Francois, P., Spite, M., Bonifacio, P., Cayrel, R., Hill, V., NLTE strontium abundance in a sample of extremely metal poor stars and the Sr/Ba ratio in the early Galaxy, A&A 530 (2011), A105

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