Non-congruent Phase Transitions
in Cosmic Matter and Laboratory

Melting point

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The theory of brown dwarfs and extrasolar giant planets

**Quasi-chemical representation**

(“Chemical picture”)

**Neutron stars**

\[ u, \, d, \, s, \, p, \, n, \, e \]

\[ u + e \Leftrightarrow d \]

\[ d \Leftrightarrow s \]

\[ p + e \Leftrightarrow n \]

\[ n \Leftrightarrow u + 2d \]

\[ (p \Leftrightarrow 2u + d) \]

\[ \mu_u, \mu_d, \mu_s, \mu_p, \mu_n, \mu_e \]

\[ \mu_u + \mu_e = \mu_d, \]

\[ \mu_d = \mu_s, \]

\[ \mu_p + \mu_e = \mu_n \equiv \mu_B, \]

\[ \mu_n = \mu_u + 2\mu_d, \]

\[ (\mu_p = 2\mu_u + \mu_d). \]

**U – O system**

Multi-molecular model

(\textit{Liquid \& Gas})

\[ U + O + O_2 + UO + UO_2 + UO_3 \]

\[ U^+ + UO^+ + UO_2^+ + O^- + UO_3^- + e^- \]

\[ U + 2O \Leftrightarrow UO_2 \]

\[ 2O \Leftrightarrow O_2 \]

\[ U^+ + e \Leftrightarrow U \]

\[ UO_3 + e \Leftrightarrow UO_3^- \]

\[ \ldots \ldots \]

\[ \mu_U + 2\mu_U = \mu_{UO2} \]

\[ 2\mu_O = \mu_{O2} \]

\[ \mu_{U^+} + \mu_e = \mu_U \]

\[ \mu_{UO3} + \mu_e = \mu_{UO3^-} \]

Endo T., Maruyama T., Chiba S., Tatsumi T.

astro-ph/0601017v1/ 2006 /
Two problems in phase transition calculation

- Construction of Equation of State (EOS)
- Phase coexistence parameters calculation
Chosen approach and fundamentals

Sketch of theoretical approach

Quasi-chemical representation for liquid & gaseous phases

**Ionic model**

(Liquid)

\[ \text{U}^{6+} + \text{U}^{5+} + \text{U}^{4+} + \text{U}^{3+} + \text{O}^{2-} + \text{O}^{-} \]

**Multi-molecular model**

(Liquid & Gas)

\[ \text{U}^+ + \text{O}^+ + \text{O}_2^+ + \text{O}^- + \text{UO}_3^- + \text{e}^- \]

**Interactions:** *(Pseudopotential components)*

- Intensive short-range repulsion
- Coulomb interaction between charged particles
- Short-range effective attraction between all particles

**Interaction corrections:** *(Modified for mixtures)*

- Hard-sphere mixture with varying diameters
- Modified Mean Spherical Approximation *(MSAE+DHSE)*
- Modified Thermodynamic Perturbation Theory \{TPT- \ \sigma(T); \ \varepsilon(T)\}
Phase coexistence parameters calculation

(two approaches)

**Ordinary way:**

Maxwell ("equal squares")
or "Double tangent" \{in $F(V)$\} construction
Plasma Phase Transitions in $\text{H}_2 + \text{He}$ plasma


Plasma Phase Transition in Fluid Hydrogen-Helium Mixtures
M. SCHLANGES (a), M. BONITZ (b), and A. TSCHTISCHIAN (b)
Thermodynamics of $\text{H}_2 + \text{He}$ plasma

(continued)

Fig. 7. Coexistence pressure for $\text{H} - \text{He}$ mixtures for different values of the mixing parameter, for the hydrogen-like plasma phase transition and for the helium-like plasma phase transition.
Standard Congruent evaporation in U-O system

Pressure - Density diagram

- Stoichiometry of coexisting phases are equal: \( x' = x'' \)
- Van der Waals loops (at \( T < T_c \)) corrected via the "double tangent construction"
- Standard phase equilibrium conditions:
  \[ P' = P'' \quad \text{or} \quad T' = T'' \quad \text{or} \quad G'(P,T,x) = G''(P,T,x) \]
- Standard critical point:
  \[ (\partial P/\partial V)_T = 0 \quad \text{or} \quad (\partial^2 P/\partial V^2)_T = 0 \quad \text{or} \quad (\partial^3 P/\partial V^3)_T < 0 \]

Pressure - Temperature diagram

- Saturation curve (Double-tangent construction)
- Melting point
- Critical point

It should be \( x' \neq x'' \)
Congruent evaporation in U-O system does not correspond to the total equilibrium (only to the partial one)

Maxwell approach
- should be rejected as non-adequately

Correct approach:
- Gibbs (+ Guggenheim) conditions
Phase equilibrium conditions in reacting Coulomb system

Phase - I

\[
\begin{align*}
\phi' \quad &\quad \text{Phase - I} \quad n_i' + n_k' + ... + n_e' \\
\text{Heat exchange} \quad &\quad T' = T'' \\
\end{align*}
\]

Particle Exchange
neutral species

\[
\begin{align*}
\mu_i'(P,T,x') &= \mu_1'(P,T,x'') \\
\mu_k'(P,T,x') &= \mu_k''(P,T,x'') \\
\end{align*}
\]

Equilibrium reactions
(reduced number of basic units)

\[
\begin{align*}
\mu_a'(P,T,x') &= \mu_a''(P,T,x'') \\
\mu_b'(P,T,x') &= \mu_b''(P,T,x'') \\
\end{align*}
\]

Uranium – Oxygen system

\[
\begin{align*}
\mu_U'(P,T,x') &= \mu_U''(P,T,x'') \\
\mu_O'(P,T,x') &= \mu_O''(P,T,x'') \\
\end{align*}
\]

Phase - II

\[
\begin{align*}
\phi'' \quad &\quad \text{Phase - II} \quad n_i'' + n_k'' + ... + n_e'' \\
\text{Impulse exchange} \quad &\quad P' = P'' \\
\end{align*}
\]

Particle Exchange
charged species

\[
\begin{align*}
\mu_1'(P,T,x') &= \mu_1''(P,T,x'') + Z_1 e \Delta \phi(T) \\
\mu_2'(P,T,x') &= \mu_2''(P,T,x'') + Z_2 e \Delta \phi(T) \\
\mu_e'(P,T,x') &= \mu_e''(P,T,x'') - e \Delta \phi(T) \\
\end{align*}
\]

NB! - Chemical potentials of charged species are not equal (Guggenheim, 1929)

Electro-chemical potentials are equal

\[
\mu_i' + Z_i e \phi' = \mu_i'' + Z_i e \phi'' \quad \Leftrightarrow \quad \Delta \phi(T)
\]

Potential drop at mean-phase interface
in equilibrium Coulomb system

\[
\text{Bulk potential}
\]

Bulk potential

(see for example: Iosilevskiy I., Encyclopedia on low-T plasmas. III-1 (suppl) 2004, P.349-428)
Non-congruent evaporation in U-O system
(Gibbs - Guggenheim conditions)

1 – Non-congruent (total) equilibrium
2 – Forced-congruent (partial) equilibrium
SC – Saturated vapor conditions
BC – Boiling liquid conditions

NB! 2-dimensional two-phase region instead of standard P-T saturation curve
• Stoichiometry of coexisting phases are different: $x' \neq x''$

NB! High pressure level of non-congruent phase decomposition
• Total phase equilibrium conditions for mixture are valid instead of the
  double-tangent construction

NB! Critical point should be of non-standard type:
  $(\partial P/\partial V)_T \neq 0$  $(\partial^2 P/\partial V^2)_T \neq 0$
  It should be instead:
  $(O/U)_{\text{liquid}} = (O/U)_{\text{vapor}}$  and  $\{||\partial \mu_i/\partial n_k||_T\}_{CP} = 0$
Non-congruent phase transformation in two-phase region

Phase Diagram $P-T$ of Non-congruent Evaporation

First liquid droplets in saturated vapor

Last vapor bubbles in boiling liquid

Oxygen depleted liquid

$! \text{Different stoichiometry}!$

Oxygen enriched vapor

$! \text{Different stoichiometry}!$
Isotherms in two-phase region

**Standard** pressure-density diagram

![Standard pressure-density diagram](image)


**Non-congruent** pressure-density diagram

- **CP** - Critical point
- **BC** - Boiling curve
- **SC** - Saturation curve
- **$T_{max}$** - Crycondentherm

- **Isothermal** phase transition starts and finishes at **different pressures**
- **Isobaric** phase transition starts and finishes at **different temperatures**
EMMI : Cosmic Matter in the Laboratory

Non-congruence in general
Main issue for study of non-congruent evaporation in U–O system

Non-congruence of phase transition in U-O system –
– is it an exception or a general rule?

Basic conclusion:

- Any phase transition in a system of two or more chemical elements must be non-congruent
- Congruent phase transition is exception

Evident contradiction

H₂O, CO₂, NH₃ . . .

Non-congruence in H₂O etc... – what does it mean?
Neptune and “hot-water” extrasolar planet GJ436b

Star: - Gliese 436 (RD)
  M ~ 22 M_\odot
  R ~ 4 R_\odot
  \Delta T ~ 2,6 days (!)
  T_{surface} ~ 500 K
  Main comp-t. – H_2O
  = « » =
  (Discovered – 2007)

Water (phase diagram)

Solid

Superionic

Ionic Fluid

Metallic

Room conditions

Pressure (Mbar)

Temperature (eV)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

Ab initio calculations
Mattsson & Desjarlais (Sandia Lab.): High energy-density water: DFT/QMD simulations (2007)

Any phase transition in high-T_high-P water must be non-congruent
Main issue of study of non-congruent evaporation in U–O system

Non-congruence of phase transition in U-O system –
– is it an exception or a general rule?

Basic conclusion
- Any phase transition in a system of two or more chemical elements must be non-congruent
- Congruent phase transition is exception

• Hypothetical example of non-congruent phase transition
Thermodynamics of H$_2$ + He plasma (continued)

Fig. 7. Coexistence pressure for H—He mixtures for different values of the mixing parameter, for the hydrogen-like plasma phase transition and for the helium-like plasma phase transition.
Thermodynamics of H$_2$ + He plasma


Plasma Phase Transition in Fluid Hydrogen-Helium Mixtures

M. Schlanges (a), M. Bonitz (b), and A. Tschtschjan (b)

Конгруэнтный фазовый переход в системе H$_2$ + He

Неконгруэнтный фазовый переход в системе H$_2$ + He

He + (H)

$T = 7'000$ K

$T = 18,000$ K

$T = 12,000$ K

$P$(Mbar)

$\log_{10}[n_i \text{ (cm}^{-3})]$
Hypothetical phase transition in H$_2$/He mixture

after Chabrier G., Saumon D., Hubbard W., Lunine J. (SCCS-1992, Rochester)

Fig. 1. Pressure and density profiles of optimized models of Jupiter (top panel) and Saturn (bottom panel), plotted as a function of mean radius. Discontinuities in the density clearly mark the boundaries of the four layers of the models: rocky core, ice mantle, metallic and molecular
Giant planets interior composition

Saturn interior composition using SCVH-95_EOS

After N. Nettelmann, R. Redmer, et al., PNP-12, Darmstadt, 2006

Optimized models of Jupiter and Saturn
(D. Saumon, G. Chabrier, W. Hubbard, J. Lunine)

He 25% 
Hydrogen 75%

He 73%

1st order PPT (?)

IR

He 25%

H 73%

H2

5000 K 1.4 Mbar
9100 K 11.6 Mbar

He %

\( T_{\text{PPT}} \) (K) 6880 6070
\( Y_I \) 0.29 0.25
\( Y_{II} \) 0.326 0.73

TABLE 1

GIANT PLANETS AND THE PLASMA PHASE TRANSITION
D. Saumon, G. Chabrier, W. B. Hubbard, and J. I. Lunine
Hypothetical phase transitions in interiors of GP-s and BD-s via “additivity approximation”

Phase diagram of H₂/He mixture in frames of “additivity approximation” is superposition of P-T phase diagrams for pure hydrogen and helium.

Dissociative Phase Transition in H₂
(Scandolo S., Bonev S., Militzer B., Galli G.)

Plasma Phase Transition in H
(Ebeling et al.)

1st Plasma Phase Transition in He
(Ebeling et al.)

2nd Plasma Phase Transition in He⁺
(Ebeling et al.)

Presence of helium relax phase transition in hydrogen <> presence of hydrogen relax phase transition in helium

(*) Pfaffenzeller O. et al. PRL 74 (13) 2599 (1995)
Phase diagram in simple mixture $\text{H}_2 + \text{He}$ could be complicated due to non-congruence

The question is:

What kind of phase transition one can expect in high-$T$ high-$P$ complex plasma?

$\text{H}_2 + \text{He} + \text{H}_2\text{O} + \text{NH}_3 + \text{CH}_4\ldots$

at $T \sim 1 – 20 \text{ kK} \& P \sim 1 – 10 \text{ Mbar}$

Typical composition in planetary science
Five layers (!) model of Saturn's interior

Table 4
Parameters of the models of Saturn

<table>
<thead>
<tr>
<th>Model</th>
<th>$Y_1$</th>
<th>$Y_2$</th>
<th>$Z$</th>
<th>$P_{1-2}$</th>
<th>$M_{\text{H} \text{O}}$ core</th>
<th>$M_{\text{core}}$</th>
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</thead>
<tbody>
<tr>
<td>MS1</td>
<td>0.267</td>
<td>0.06</td>
<td>0.30</td>
<td>3.0 0.42</td>
<td>10.66</td>
<td>16.18</td>
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<td>MS2</td>
<td>0.171</td>
<td>0.06</td>
<td>0.40</td>
<td>3.0 0.64</td>
<td>4.58</td>
<td>8.59</td>
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<tr>
<td>MS3</td>
<td>0.225</td>
<td>0.06</td>
<td>0.30</td>
<td>2.0 0.44</td>
<td>9.88</td>
<td>15.06</td>
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<tr>
<td>MS4</td>
<td>0.133</td>
<td>0.06</td>
<td>0.40</td>
<td>2.0 0.67</td>
<td>4.02</td>
<td>7.65</td>
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<td>3.0 0.46</td>
<td>6.33</td>
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<td>6.74</td>
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<td>MS9</td>
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<td>0.30</td>
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<td>11.16</td>
<td>11.66</td>
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<td>MS10</td>
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<td>0.30</td>
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<td>MS11</td>
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<td>0.30</td>
<td>3.0 0.41</td>
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<tr>
<td>MS12</td>
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<td>0.30</td>
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<td>6.15</td>
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<td>MS14</td>
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<td>MS15</td>
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<td>0.25</td>
<td>0.30</td>
<td>3.0 0.007</td>
<td>0.76</td>
<td>0.76</td>
</tr>
</tbody>
</table>

$Y_1=0.10$, $Y_2=0.25$, $Z=0.02$, $I/R=2.2$

Saturn

$Y_1$ = mass fraction He

$Z_i$ = mass fraction (H$_2$O, NH$_3$, CH$_4$ + Fe + Ni)

I = “Ices” (H$_2$O, NH$_3$, CH$_4$)      R = Rocks + Fe + Ni
Non-congruent phase transitions in astrophysical objects

**H$_2$O, CH$_4$, NH$_3$ in giant planets**

After N. Nettelmann, R. Redmer et al. (2007)

"Hot-water" extrasolar planet GJ 436b

**GJ436b**

- Star: Gliese 436 (RD)
- $M \sim 22M_\odot$
- $R \sim 4R_\odot$
- $\Delta T \sim 2.6$ days (!)
- $T_{\text{Surf.}} \sim 500$ K
- Main Comp. – H$_2$O
  - = «» =
  - (Discovered in 2007)

Chemical composition of Neptune [1]:
- 56% water
- 36% methane
- 8% ammonia

What kind of phase transition one can expect in high-$T$ high-$P$ complex plasma?

$H_2 + He + H_2O + NH_3 + CH_4 \ldots$

at $T \sim 1 – 20$ kK & $P \sim 1 – 10$ Mbar

Phase diagram in simple mixture $H_2 + He$ may be very complicated due to non-congruence

The question is:

Typical composition in planetary science
Conclusions and perspectives

- Non-congruence of phase transitions in \( \text{H}_2/\text{He} \) mixture can ‘provoke’ to the \( \text{H} \leftrightarrow \text{He} \) separation in interiors of Jovian and Extrasolar planets and Brown Dwarfs.

- New experiments are desirable for study of discussed non-congruence for phase transition in \( \text{H}_2/\text{He}/\text{H}_2\text{O}/\text{NH}_3/\text{CH}_4 \) mixture.

- Heavy Ion Beam volumetric heating is very promising tool for adiabatic compression of the \( \text{H}_2/\text{He}/\text{H}_2\text{O}/\text{NH}_3/\text{CH}_4 \) mixture just under conditions of Jovian and Extrasolar planets and Brown Dwarfs.
EMMI: Cosmic Matter in the Laboratory

Non-congruence in general
Hypothetical non-congruent phase transitions

*(short list - Swedish buffet)*

**Terrestrial applications:**

- **Uranium- and Plutonium-bearing compounds:**
  - $\text{UO}_2$, $\text{PuO}_2$, $\text{UC}$, $\text{UN}$, ... etc.,
- **Metallic alloys:** ($\text{Li}$-$\text{K}$-$\text{Na}$, etc.
- **Oxides:** ($\text{SiO}_2$ etc.
- **Hydrides of metals** ($\text{LiH}$, etc.
- **Ionic liquids and molten salts:**
  - alkali halides ($\text{NaCl}$, etc.), ammonium halides ($\text{NH}_4\text{Cl}$, etc.)
- **“Dusty” and Colloid plasmas:**
  - (Coulomb system of macro-ions $+Z$ and micro-ions: $+1$, $-1$)

**Non-Congruence in Cosmic Matter:**

- **Plasma Phase Transitions in mixture:** $\text{H}_2$/He/$\text{H}_2\text{O}$/NH$_3$/CH$_4$
  - in Giant Planets, Brown Dwarfs and Extra-Solar Planets,
- **Phase Transitions in White Dwarfs,**
- **Phase Transitions in Neutron Stars,**
- **Phase Transitions in “Strange” Stars** (quark-hadron transition ... etc.)

What kind of phase transition one can expect in high-$T_{\text{high}}$-$P$ complex plasma?

$\text{SiO}_2 + \text{FeO} + \text{Al}_2\text{O}_3 + \text{CaO} + \ldots$
What kind of phase transition one can expect in high-\( T \) high-\( P \) complex plasma?

\[ \text{SiO}_2 + \text{FeO} + \text{Al}_2\text{O}_3 + \text{CaO} \]

\( T \sim eV \) & \( P \sim \text{GPa} \)

The question is open

**NB !**

Phase transition in each constituent (\( \text{SiO}_2, \text{FeO}, \text{Al}_2\text{O}_3, \text{CaO} \ldots \)) must be **non-congruent**!

Phase transitions in the mixture must be **non-congruent** moreover!
Conclusions and perspectives

- **Non-congruence** of phase transitions in $\text{SiO}_2 + \text{FeO} + \text{Al}_2\text{O}_3 + \text{CaO}$ (+ $\text{H}_2\text{O}$) mixture can ‘provoke’ to the $\text{Si} \Leftrightarrow \text{O} \Leftrightarrow \text{Fe} \Leftrightarrow \text{Al} \Leftrightarrow \text{Ca}$ (+ $\text{H}_2\text{O}$) () separation in the high-$T$-high-$P$ impact plume of *Lunar ground* in LCROSS experiment.

- New experiments are desirable for study of discussed **non-congruence** for phase transition in $\text{SiO}_2 + \text{FeO} + \text{Al}_2\text{O}_3 + \text{CaO}$ mixture.

- **Heavy Ion Beam** heating is very promising tool for isochoric compression *and* adiabatic release of the $\text{SiO}_2 / \text{FeO} / \text{Al}_2\text{O}_3 / \text{CaO}$ mixture just under conditions of LCROSS experiment.

- **Surface Laser Heating** (PHELIX) is very promising tool for non-congruent evaporation *and* expansion in the $\text{SiO}_2 / \text{FeO} / \text{Al}_2\text{O}_3 / \text{CaO}$ mixture just under conditions of LCROSS experiment.
High-Temperature evaporation in $\text{SiO}_2$ - is it congruent or not?

Fast Optical Discharge Propagation through Optical Fibres under kW-Range Laser Radiation


1: Fiber Optics Research Center at the A.M. Prokhorov General Physics Institute, RAS
38 Vavilov Street, 119991 Moscow, Russia, labuf@fo.gpi.ru
2: Institute for High Energy Density, RAS, efremov@ihed.ras.ru, 3: A.M. Prokhorov General Physics Institute, RAS

Fig.1. Pictures of F2 fibre after OD propagation. 1–damaged core of the fibre after fast OD propagation. The double-sided arrow indicates 600μm diameter of the fibre. 2–damages of the fibre core on an enlarged scale (the vertical dimension of the frame is 100μm): 2a–region of intermediate stop of OD, 2b–final stop point of fast OD. 3–for comparison: damaged fibre core after slow OD propagation: 3a–at the distance of 1mm from the stop point, 3b–stop point of the slow OD after laser beam cut off by mechanical shutter. The scale is the same as for part 2. In all frames the laser radiation propagated from right to left.
High-Temperature evaporation in $\text{SiO}_2$ - is it congruent or not?

Parameters of non-congruent evaporation in $\text{SiO}_2$ strongly depend on the rapidity of phase transformation!
Non-congruence in exotic situations

(di scussi on)
Non-congruence in exotic situations

( discussion )

Non-congruence in compact stars

The New Physics of Compact Stars
Compact stars

White dwarfs, Neutron stars, “Strange” (quark) stars, Hybrid stars

Neutron and “Strange” Stars

Hybrid Stars
Quark core + Hadron Crust

Рис. 65. Массы планет (в единицах массы Земли) и их среднее расстояние от Солнца [371]
Hybrid ("strange") white dwarfs


Ordinary WD

Strange WD

\[
\text{Phase transition?}
\]

Jump-like? or Extended?
Hypothetical phase transitions in interior of compact stars: are they **CONGRUENT** or **NON-CONGRUENT**?

First quark droplets in hadron matter

Last hadron bubbles in quark matter
Structured Mixed Phase Concept ⇔ "Pasta"

The sequence of five (or more?) phase transitions!

Uniform (nucleons) → Drops → Rods → Slabs → Bubbles → Uniform (quarks)
Non-congruence in exotic situations (mesoscopic scenario)

Structured Mixed Phase $\Leftrightarrow$ "Pasta" plasma

‘Pasta’ plasma – hadron-quark phase transition in interior of neutron stars
   (‘Mixed phase’ of Glendenning et al. 1992)
   - Charged quark droplets (rods, slabs) in equilibrium hadron matter
   - Charged hadron bubbles (tubes, slabs) in equilibrium quark matter

Heiselberg and Hjorth-Jensen
Phase Transitions in Neutron Stars

T.Maruyama, T.Tatsumi, T.Endo, S.Chiba
Pasta structures in compact stars

"Pasta" plasma:
- "Spaghetti" phase, "Lasagne" phase . . . . .
Non-congruence in exotic situations (mesoscopic scenario)

Structured Mixed Phase Concept ⇔ “Pasta”

Schematic picture of pasta structures. Phase transition from blue phase (left-bottom) to red phase (right-bottom) is considered.

Pasta structures in compact stars

Maruyama T., Tatsumi T., Endo T., Chiba S.
Hypothetical phase transitions in ultra-dense matter: are they CONGRUENT or NON-CONGRUENT?

Phase diagram of quark-hadron matter

After Fridolin Weber, WEHS Seminar, Bad Honnef, 2006
After David Blaschke, WEHS Seminar, Bad Honnef, 2007

Strange matter, a stable form of quark matter containing a large fraction of strange quarks, may have been copiously produced when the Universe had a temperature of \( \sim 100 \) MeV. We study the evaporation of lumps of strange matter as the Universe cooled to 1 MeV. Only lumps with baryon number larger than \( \sim 10^{-7} \) could survive. This places a severe restriction on scenarios for strange-

Strange matter is a form of quark matter that has been conjectured to be stable at zero temperature. If heated to a temperature \( T \geq 2 \) MeV, a strange-matter lump evaporates nucleons from its surface. We show that at higher temperatures \( T \geq 20 \) MeV, strange matter boils, with bubbles of hadronic gas forming and growing throughout the interior. Strange matter, or any other phase which resembles strange matter, could not have survived this process in the early Universe.
Hypothetical phase transitions in ultra-dense matter are they **CONGRUENT** or **NON-CONGRUENT**?

**Quark-Hadron Phase Diagram**

The problem of non-congruence for the Quark-Hadron phase transition is relevant!

Iosilevskiy I. / Int. Workshop “Physics of HEDM”, JINR, Dubna, Russia, 2008
Electrostatics of Quark-Hadron Interface

Nuclear Crust on Strange Mater

$E \sim 10^{17} - 10^{19} \text{ V/cm}$

Strange matter

Gap!!

After Fridolin Weber, WEH Seminar, Bad Honnef, 2006
**Conclusions and Perspectives**

- **Non-congruent** phase transition is **general** phenomenon.

- **Non-congruent** phase transition is **universal** phenomenon.

- **Non-congruent** phase transition is **interesting** phenomenon.

- It is **promising** to investigate non-congruent phase transitions **experimentally** in particular with **intense laser** and **heavy ion** heating.

- It is **promising** to investigate non-congruent phase transitions in **direct numerical simulations** ("numerical experiment") DFT_MD, PI MC, WP_MD...

- If one takes into account hypothetical **non-congruence** of **phase transitions** in **cosmic matter** objects (*planets, compact stars etc.*) he should **revise** totally the **scenario** of all **phase transformations** in these objects.
Thank you!

Non-Congruent Phase Transitions in Cosmic Matter and Laboratory

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