High-Intensive and Cumulative Processes and Phenomena

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Нам не дано предугадать,
как слово наше отзовётся.
Ф. И. Тютчев

We can't predict to-day
How our words will sound tomorrow
Ph. I. Tyutchev

Introduction

1. An outspoken fruitful idea starts to live independently. It is lucky if it gets into the environment where it can join other ideas and be used. And it is especially lucky if its author can influence its development for a certain period of time.
2. Sometimes an almost forgotten, undemanded in time being born the idea is perceived as a new one, e.g., ***bubble collapse in incompressible liquid*** (Besant, 1859; Rayleigh, 1917). The new time sets new tasks for this idea and opens new possibilities for its use. Such an idea has its first author, but it is perceived in the appearance of its second birth – ***cavity collapse in compressible media***.

3. Such favorable working atmosphere naturally formed under the influence of Evgeny Ivanovich Zababakhin. I believe that we still feel it nowadays.
4. In this presentation we will discuss some ideas, outspoken and cultivated by E.I. Zababakhin or implied from discussions with him. Trends of their development will be shown.
5. The presentation will be in the form of a free summary on the topic – an essay (with scientific content).
6. All topics are “genetically” related.

Note

Essay *(Fr. essai – experiment, sketch) – a genre of philosophical, critical, historical, biographical, publicistic prose that combines an individual position of the author with informal narration, oriented at improvisational apprehension.*

BACKGROUND

Background and the flow

- 1944-1947 – Ballistics Department at **ВВАИ им. Жуковского**.
- 1947 – Thesis ***“ The Studies of the Processes in a Converging Detonation Wave”.***
- End of 1947 – beginning of1948 – professor at Ballistics Department, junior research scientist at the Institute of Chemical Physics.
- From April1947 – junior research scientist at Design Bureau -11.

Level of knowledge

1. L. Landau, E. Lifshitz, Continuum mechanics, OGIZ, 1944

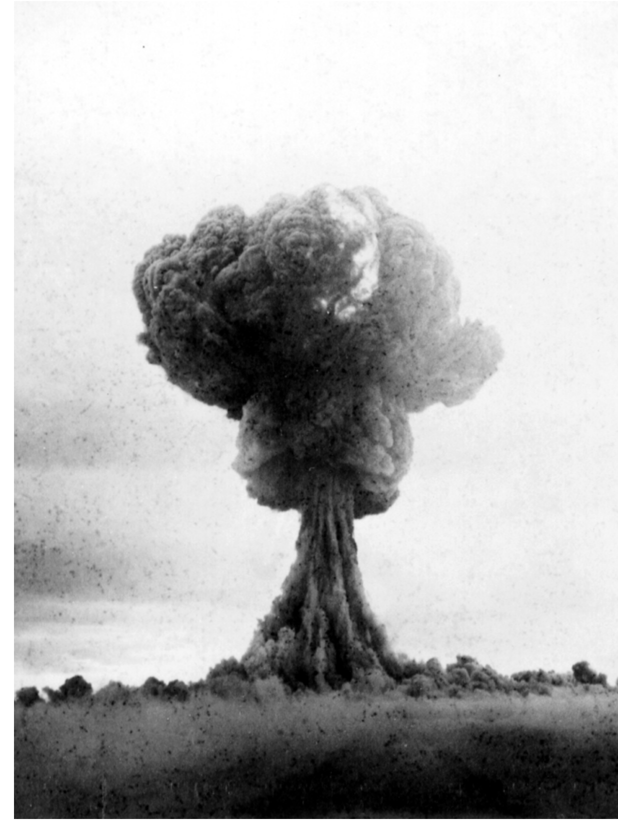
2. G. Guderley, Strake kugelige und zylindrische Verdichtungsstosse in der Nane des Kugelmittelpunktes bzw. Der Zylinderachse, Luftfahrtforschung 19, #9 (1942).

3. L.D. Landau and K.P. Stanyukevich, Self-similar Converging Shock Wave, 1944 , published in the book by K.P. Stanyukevich “Unstable Motion of Continuum Media”, M., Gostekhizdat, 1955.

4. L.D. Landau, K.P. Stanyukevich . On Studies of Condensed HE Detonation // DAN USSR. 1945. Vol. 46, #9. Pp. 399-402.

START AND TAKE-OFF (1948-1955)

Instrumental tower at the test site



Explosion of RDS-1

First results (1948-51)

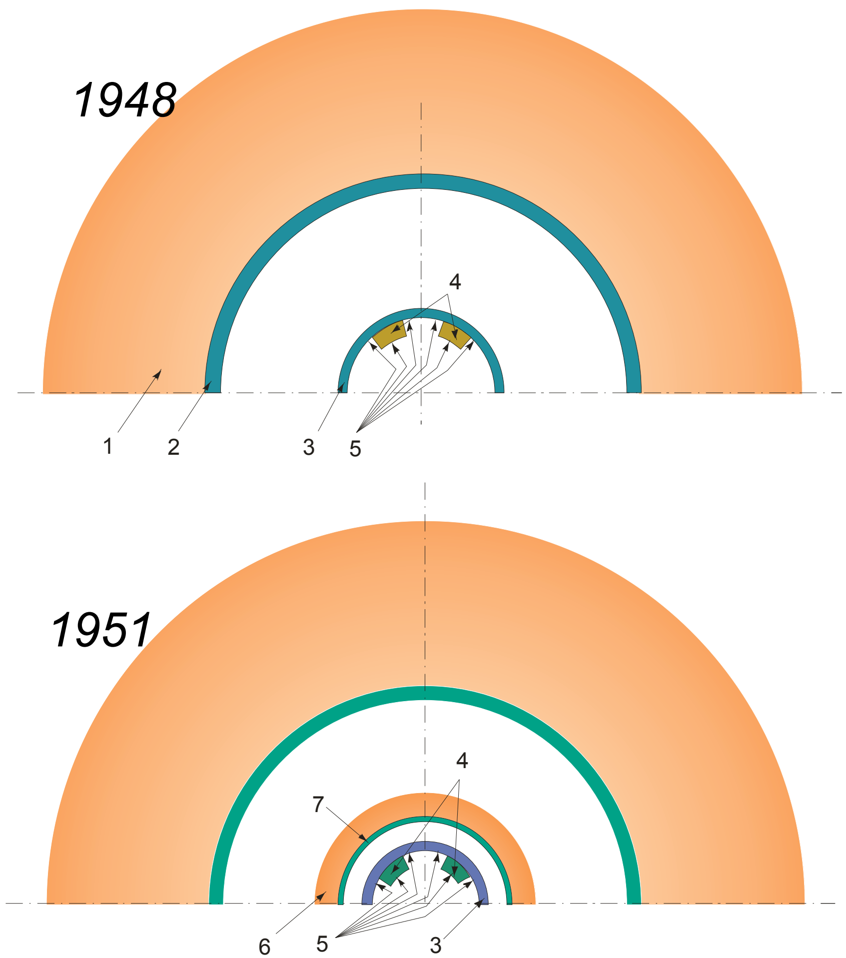
- Development of approximate computational methods of hydro-gas-dynamic (GD) flows in dense media*:
  - Task: description of detonation (DW) and shock waves (SW), energy transport from layer to layer, including HE, layer and shell flight, collision of layers etc..
  - Methods: incompressible shells, acoustic approximation, strong waves, self-similar convergent shock wave, self-similar convergence of a compressible shell.
- Description of properties of HE and real materials in high-intensive GD processes (*E.I. Zababakhin. Some Questions of Explosion Gas Dynamics, Snezhinsk, 1997)*
- Applications in calculations:
  - Experimental mockups and RDS-1 system,
  - Experimental assemblies (planar and spherical) to measure shock compressibility,
  - Substantiation of GD systems of a new type – proposal by L.V. Altshuler, E.I. Zababakhin, Ya.B. Zel’dovich, K.K. Krupnikov (AZZK).
    Yu.B. Khariton, Yu.N. Smirnov, Myths and Realities of the Soviet AtomicProject (Arzamas-16, 1994)

These studies promoted

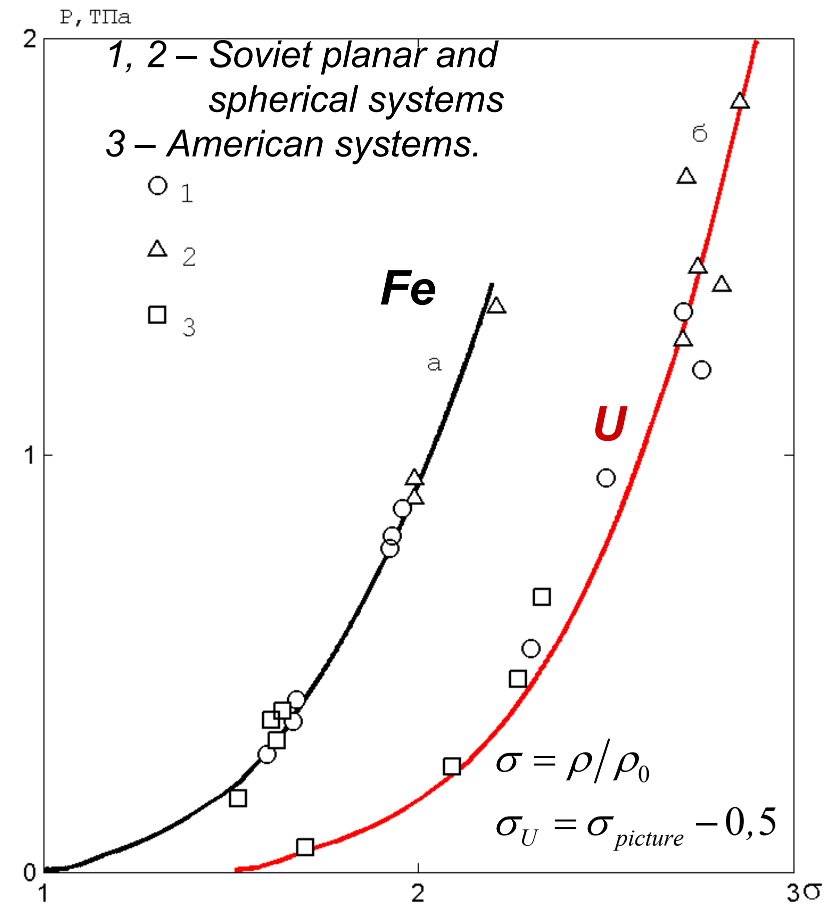
1. Development of numerical methods and creation of computational complexes;
2. Development of theoretical studies
    1. High-intensive and cumulative (HI&C) processes, their stability and evolution;
    2. Thermodynamic (TD) properties of materials (wide-range equations of state) and properties of dissipative processes, transport processes that break adiabaticity and local TD equilibrium.
3. Development of experimental studies and advance in new applications for high-intensive and cumulative processes and phenomena.
4. Studies of their display in nature.

A characteristic feature of these and subsequent publications by E.I. Zababakhin and his colleagues was their practical orientation at high theoretical level. Studies in paragraph 4 were generally conducted initiatively, and later, in 990-2005, a part of these studies was supported by ISTC grants.

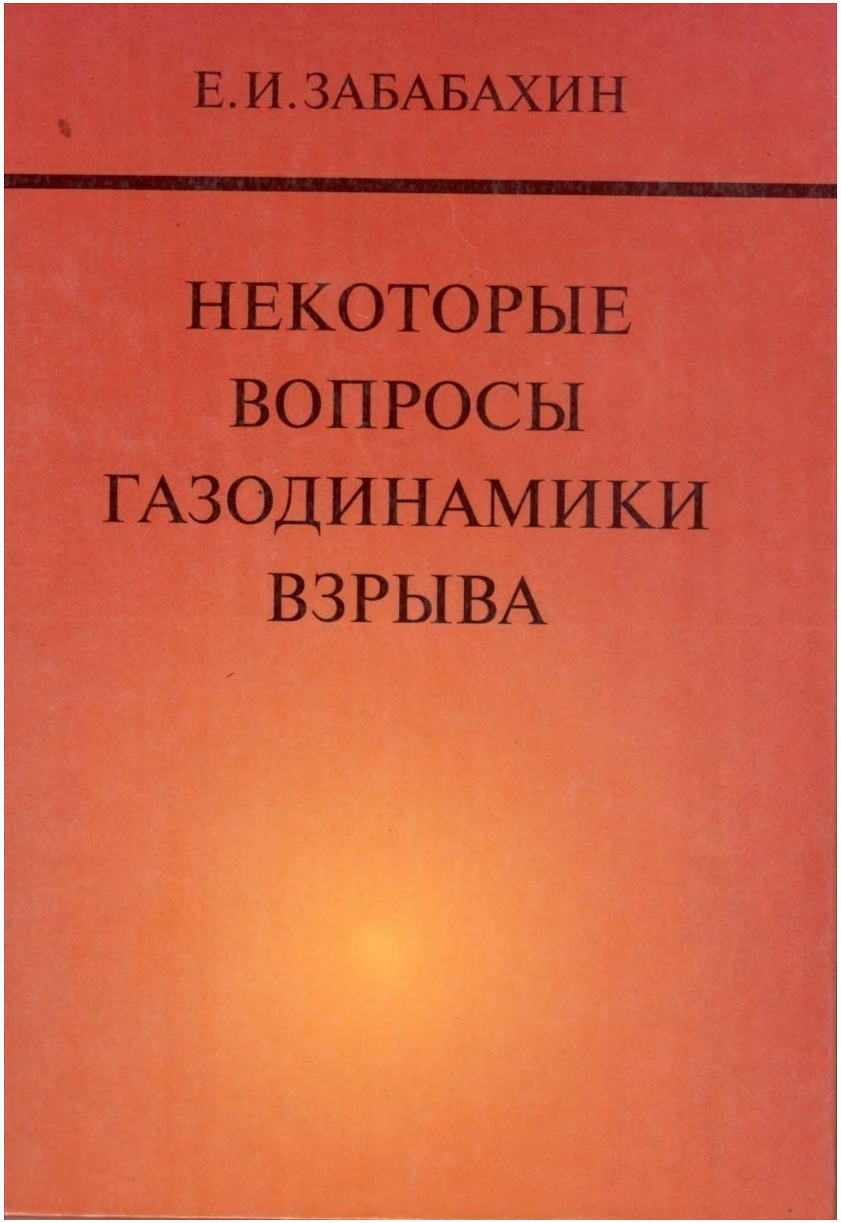
Application of AZZK proposals in experiments on shock compressibility



L.V. Altshuler, K.K. Krupnikov, R.F. Trunin, N.V. Panov, Explosive Laboratory Equipment to Study Material Compression in Shock Waves, UFN, 1996, vol.196, #5, p.575.



1. L.V. Altshuler, K.K. Krupnikov et al., ZhETF, **34**, p. 874, 1958.
2. L.V. Altshuler, A.A. Bakanova, I.P. Dudoladov, M.I. Brazhnik et al., ZhETF, **38** (3), p.790, 1960.



Intermediate Results

- Methods and explosive devices to obtain data on shock compressibility of materials.
- RDS-2 –1951.
- 1952-1953 – lectures on gas dynamics. Published in 1997.
- Equations of state of dense media; emphasis on phase transitions and strength properties of materials in dynamic processes.
- Cascade and layered systems, periodic layering...
- RDS-6s – 1953
- RDS-37 – 1955

USSR Atomic Project: Documents and Materials. – Vol. II, Atom Bomb. 1945—1954", Book1, edited by L.D. Ryabev.

Sungul landing operation

(1955)

Cumulation phenomenon*

*1. **Energy cumulation** is a considerable increase of energy density* ε_1 *in a certain part of a system (due to compression and/or temperature increase) as compared to the initial* ε_0 *by means of self-organization or external organization of the flow during the process. Cumulation is not limited to Mechanics of continua (MC).*

2. Cumulation can dramatically change the character of a process, or, more precisely, trigger another process.

3. *Flows with cumulation* (CF) are a subclass of self-similar solutions of MC equations, including those in active and dissipative media.

4. There are isentropic and adiabatic CF. In some cases triggering of dissipative processes (viscosity, heat conductivity) changes the process development, but preserves cumulativness.

E.I. Zababakhin, Shock waves and their cumulation. ZhETF, 1957, vol. 33, #2(8).

E.I. Zababakhin, M.N. Nechaev, Filling of bubbles in a viscous liquid, PMM, 1960, vol. 24, #6.

E.I. Zababakhin, Shock waves in layered systems, ZhETF, 1965, vol. 49, #2 (8).

E.I. Zababakhin, Energy cumulation and its boundaries, UFN, 1965, vol. 85, #4.

E.I. Zababakhin, B.P. Mordvinov, Examples of stationary unlimited cumulation, ZhETF, 1965, vol. 48, p. 1.

E.I. Zababakhin, V.A. Simonenko, Converging shock wave in heat-conducting gas, PMM, 1965, vol. 29, # 2.

K.V. Brushlinsky, Ya.M. Kazhdan. On self-similar solutions of some gas dynamics problems // Achievements of math. science. 1983. Vol. 18. #2(110).

* ***Like appearance to the people***. *(In more detail in I.E. Zababakhin's presentation*

5. Practical applications

5.1. To get insight into the evolution of processes, to obtain simplified assessment of results, and verify models and codes.

5.2. To reach states inaccessible in other laboratory experiments.

5.3. To reach states when radically new processes are triggered (phase and chemical transition, fission or fusion).

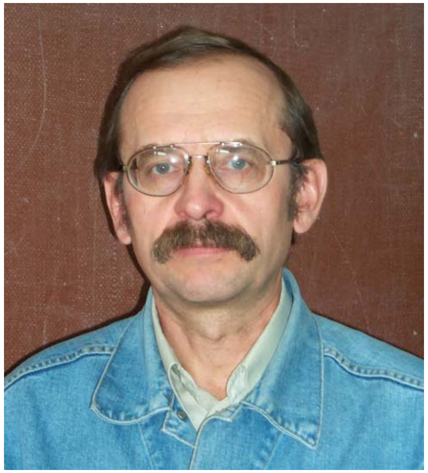
5.4. To get insight into a wide range of natural phenomena

6. Primary sources of energy may be condensed HE, sources of stored electromagnetic energy, powerful laser systems, nuclear power (fission and fusion), kinetic energy, gravitational energy…

7. Cumulative modes can be created under external impact in quasi-stationary or periodic “power” fields.

A look from the past

Into the "future" that has become a reality

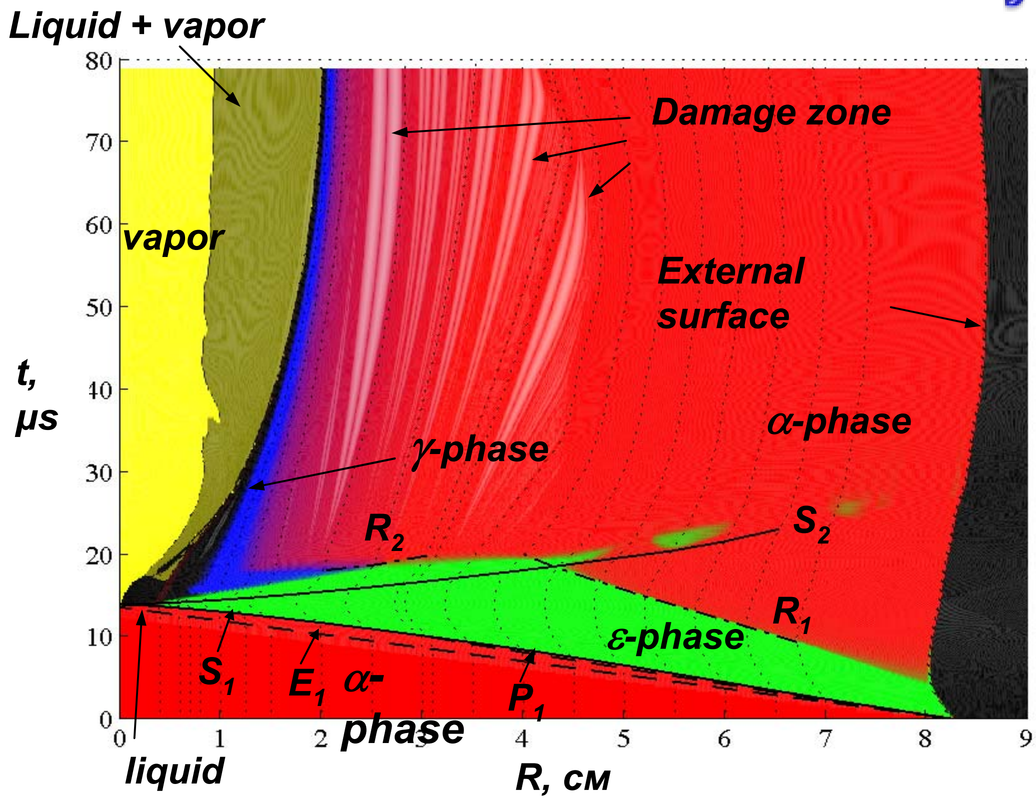


A.V. Petrovtsev

G.V. Kovalenko

E.A. Kozlov

Compression of a steel ball at converging detonation in HE layer



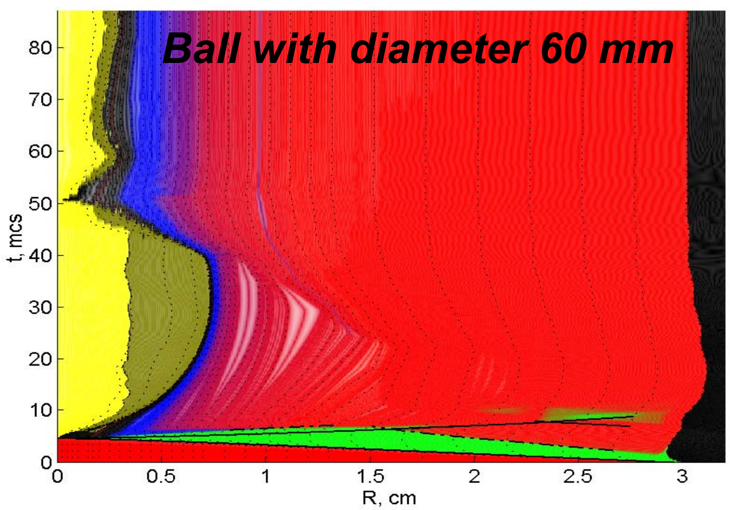
- Ball diameter 166 mm.
- Detonation of HE layer creates a "triangular" loading pulse at the external surface of the ball .
- The flow near the center has a multi-wave structure E_1-P_1-S_1 that depends on loading parameters. The material is transferred into a high-density ε phase.
- Melting occurs on the deep radius in the main plastic wave front S_1.
- Reflection from the center $S_1 \rightarrow S_2$ results in the appearance of a rarefaction wave.

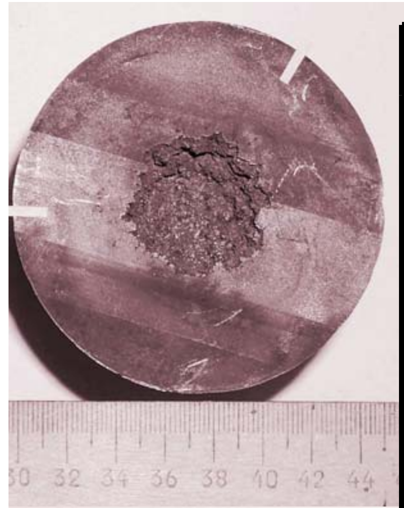
The material relaxation occurs in rarefaction waves propagating from the external surface and from the center. The material turns into vapor, vapor-liquid mixture, γ-phase and, in the main part of the sample, into α-phase .

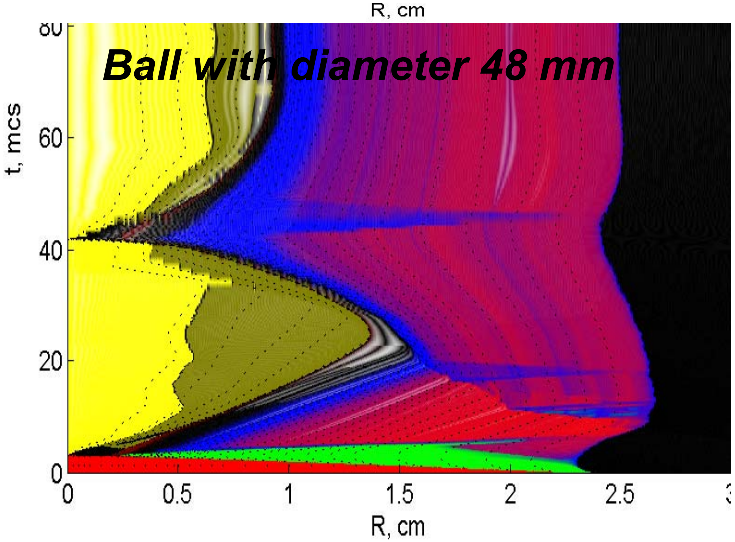
- Shock rarefaction waves R_1 and R_2 are formed on relaxation segments.
- Interaction of rarefaction waves causes processes of damage formation. At the final stage, healing of damages takes place.

[1] Г.В.Коваленко, Е.А.Козлов, А.В.Петровцев. XIII ХНЧ, РФЯЦ-ВНИИЭФ, 2006, с.129-136
[2] V.V.Dremov, G.V.Kovalenko, E.A.Kozlov, A.V.Petrovtsev, D.A.Varfolomeev et.al. SCCM-2007, AIP CP 955, 2008, pp.251-254

The influence of loading intensity on cumulation







Sample		∅60	∅48
Residual strain	Э:	1.016	1.024
	P:	1.006	1.020
Failure region R_{fr0} (ΔR_{fr}), cm	Э:	1.2 (1.6)	Every-where
	P:	1.2-1.7	1.5
Recrystall. zone boundary R_{rc0} (ΔR_{rc}), cm	Э:	1.1 (1.6) 0.7(1.85)	Every-where
	P:	1.1 0.7	Every-where
Mass of molten iron, M_{liq},г	Э:	1.73	32.9
	P:	4.1(4.8)	13.7 (37.0)

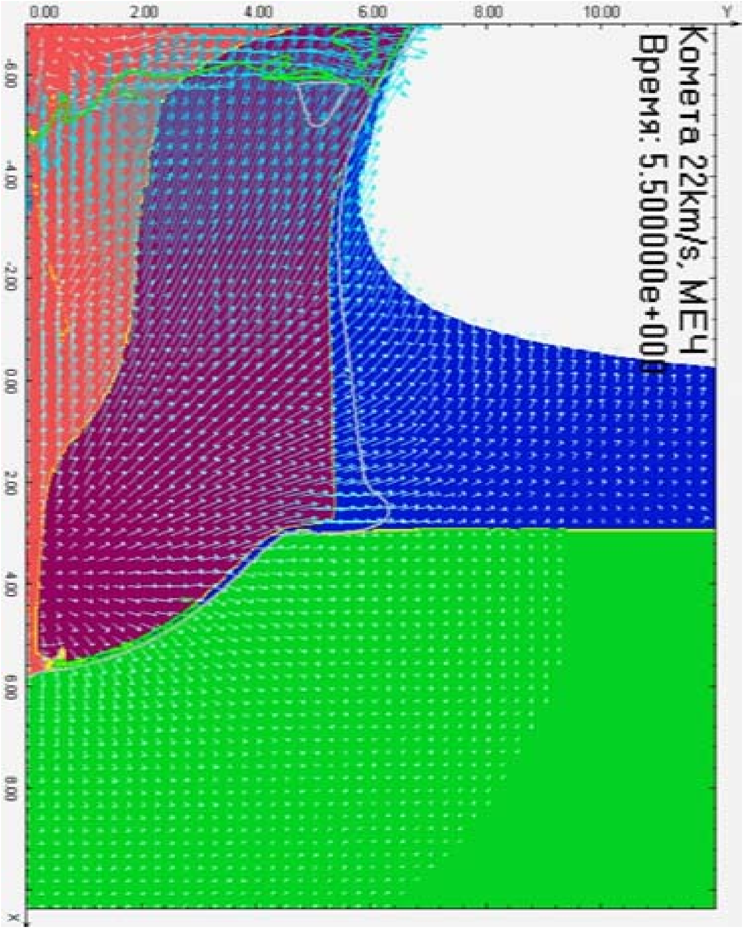
1. Higher loading intensity, repeated cavity focusing.

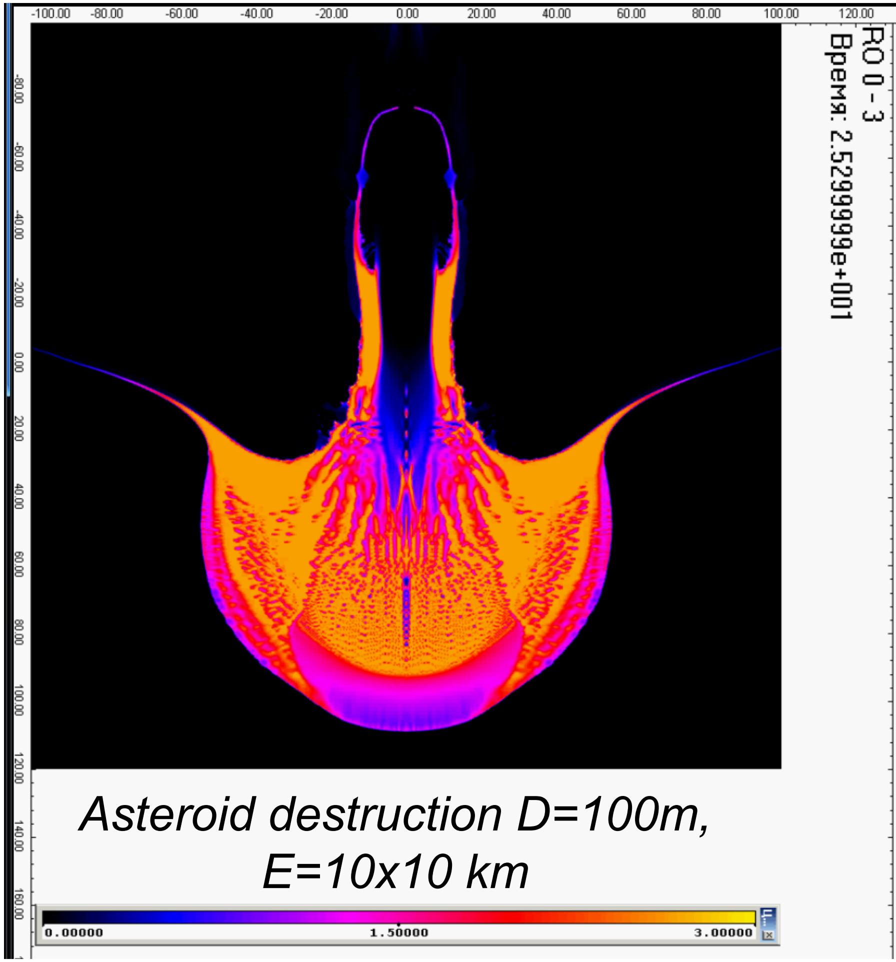
2. More intensive heating results in the increase of melt and mass of the new high-temperature γ-phase.

3. Higher damage intensity and incomplete healing of damages.

[1] *E.A.Kozlov, S.A.Brichikov, A.V.Petrovtsev, G.V.Kovalenko et.al. SCCM-2007, AIP CP 955, 2008, pp.251-254*

Strong explosion phenomena (SEP)





Asteroid destruction D=100m, E=10x10 km

Strong explosions (SEs) and cumulative phenomena (CP)

1. Cumulative phenomena that entail creation of conditions for high additional energy release and intense transitions in corresponding area (in chemical transition reactions, nuclei fission and fusion etc. constitute a mater of special interest.

2. For generality, we will call such phenomena as ***strong explosions*** (SEs). We will not be interested in what happens in devices per se or in the energy release areas. We will consider the accompanying processes.

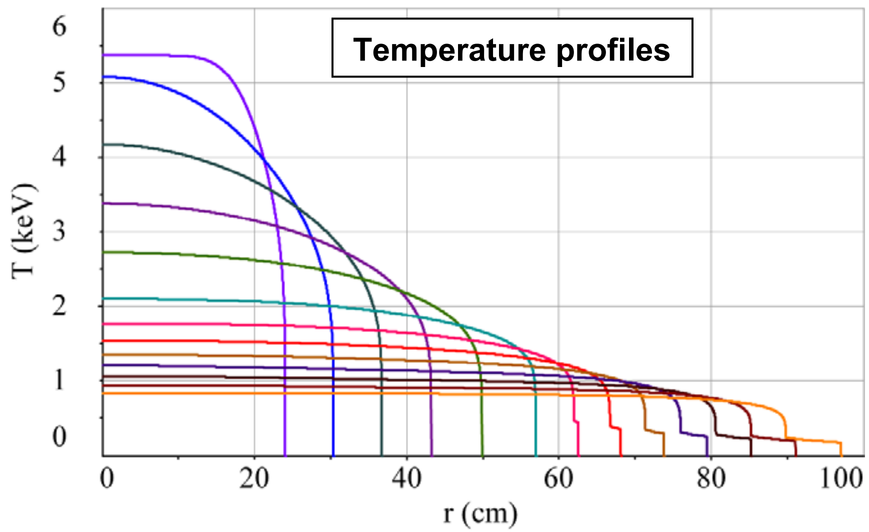
3. According to the nature of processes, SEs are related to phenomena pertaining to high-velocity impacts (for example, astronomical bodies), or focusing of a powerful laser pulse, or discharge of a powerful electromagnetic charge.

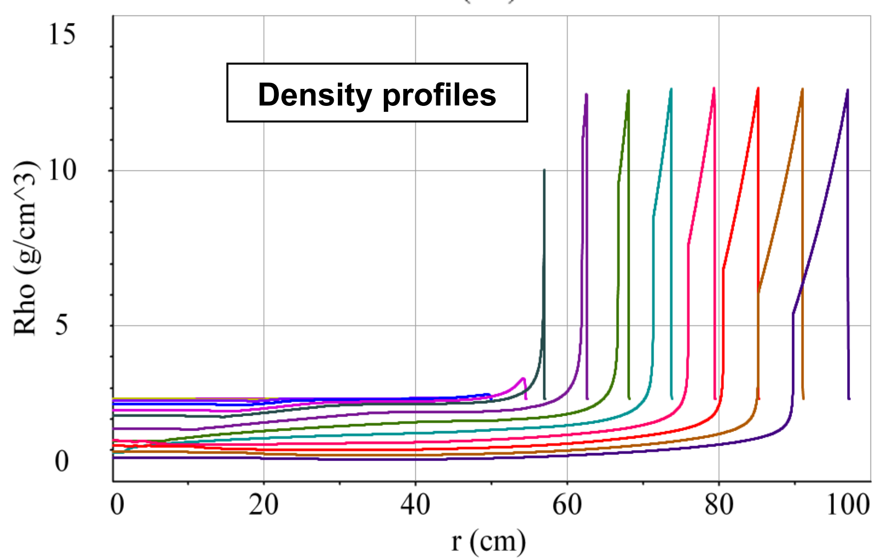
4. In some cases such phenomena trigger cumulative processes.

SEs in the air

1. The processes involved in strong explosions in the air were published practically simultaneously with their understanding. They are described in full detail in the book by Ya.B. Zel'dovich and Yu.P. Raizer. However, some processes related to SEs were considered in 1961 and later, at the initiative of E.I. Zababakhin or under his support. ***Ya.B. Zel'dovich, A.S. Kompaneyets, On the Heat Propagation Theory at Temperature-Dependent Heat Conductivity, in coll. vol., dedicated to the 70th anniversary of Academician A.F. Ioffe, M.: Publishing House of USSR Academy of Sciences,1950.***
2. Strong explosions in dense media. It was necessary to account the smaller linear scale of the thermal stage, and the condensed state of the media. In particular, precise knowledge of TD properties of different geological materials was required.

Strong explosions in dense media





Change of energy transport mode TW→SW

Attenuation of a thermal wave

Generation of a shock wave

Media properties

- "Heat conductivity"
- Equation of state

$$P = P_c(\rho) + P_T(\rho, T); \quad \varepsilon = \varepsilon_c(\rho) + \varepsilon_T(\rho, T)$$

$\rho_0 c_0{}^2$ **Gases**

Condensed media

$$r_d = \left(E_0 / \rho_0 c_0{}^2 \right)^{1/3}$$ -Dynamic radius of explosion

E_0 - Explosion energy

Thermal wave→ Shock wave

- Change of energy transport modes
  - Thermal → Gas-dynamic

$$r_{T\to G} = a(n,\gamma)\left(\frac{\kappa_0{}^2 E_0{}^{2n-1}}{B^{2(n+1)}\rho_0{}^{2n+2m+1}}\right)^{1/(6n-1)} .$$

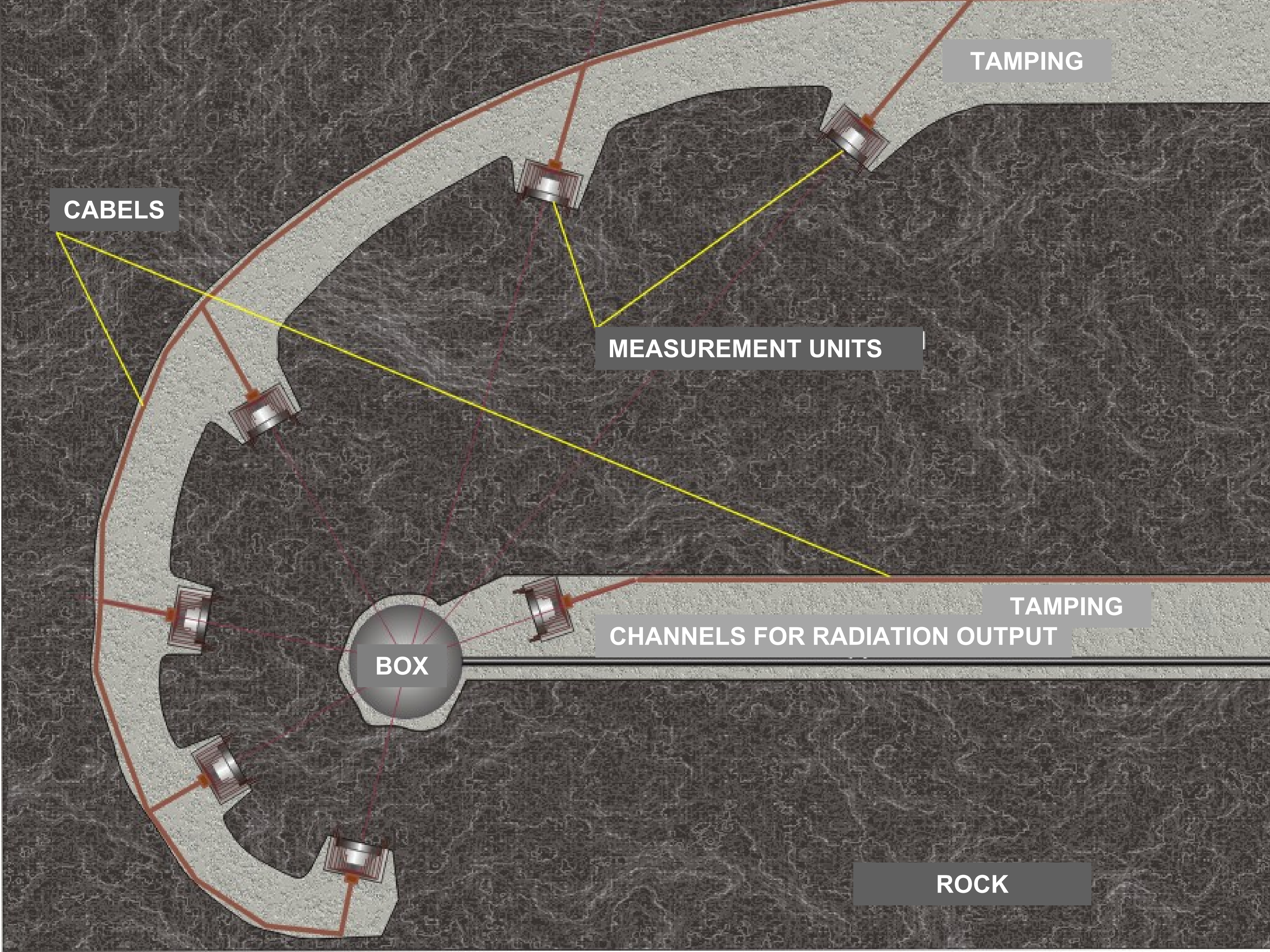
$$P = B\rho T \qquad \kappa_0 = 4l_0 ca/3 \qquad l = l_0\, T^{n-3}/\rho^m$$

$$\varepsilon_{thr} = a\,T^4 \qquad r_{T\to G}(\text{см}) \simeq 20\cdot\left[E(\text{кт})\right]^{0,315}$$

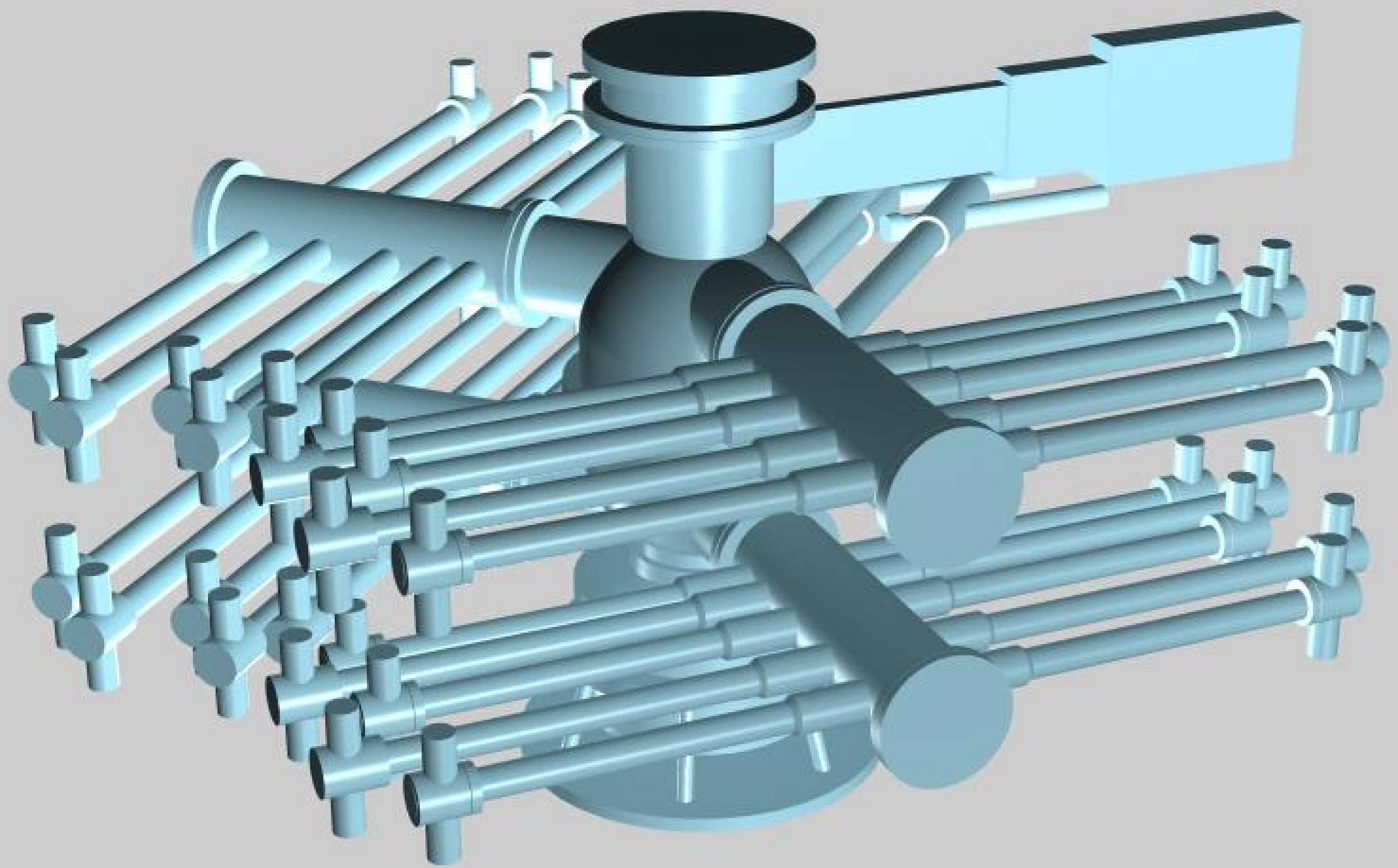
Parameter Medium	High phase density ρ_0 g/cm^3	Initial density ρ_{00} g/cm^3	Sound velocity c_0 km/s	Dynamic radius r_d $m/km^{1/3}$	Mode change radius E_0 = 1 km at $r_{T\to G}$ *(m)*
Air		1,3 10^{-3}	0,365	289	4,7
Water		1	1,5	12,3	0,34
Rock salt		2,16	3,9	5,03	
Quartzite	4,21	2,65	9,15	2,28	~ 0,20
Granite	3,64	2,56	6,33	3,06	~ 0,20
Aluminum	2,7	2.7	5,20	3,85	~ 0,14
Iron	7,85	7.85	3,80	3,33	~ 0,11

Strong explosions to study material properties and processes

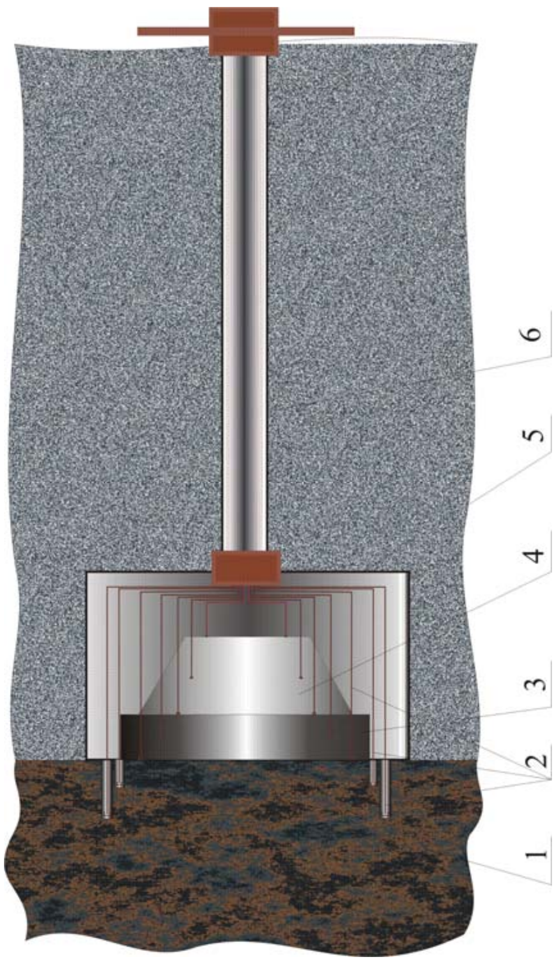
1. *Shock compressibility*
   - *To build wide-range equations of state (60 units with contact sensors);*
   - *To refine theoretical models beyond the area of quantum-static approach applicability.*
2. *Assessment of non-linear heat conductivity.*
3. *Study of kinetics of polymorphous transitions of rocks.*
4. *Integral assessment of applied equations of state.*

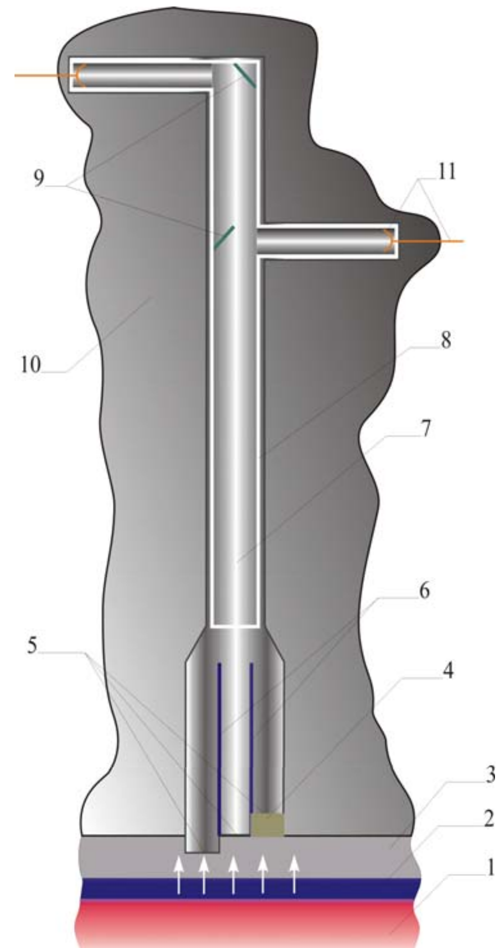

TAMPING
CABELS
MEASUREMENT UNITS
TAMPING
CHANNELS FOR RADIATION OUTPUT
BOX
ROCK

Experiment of 1983

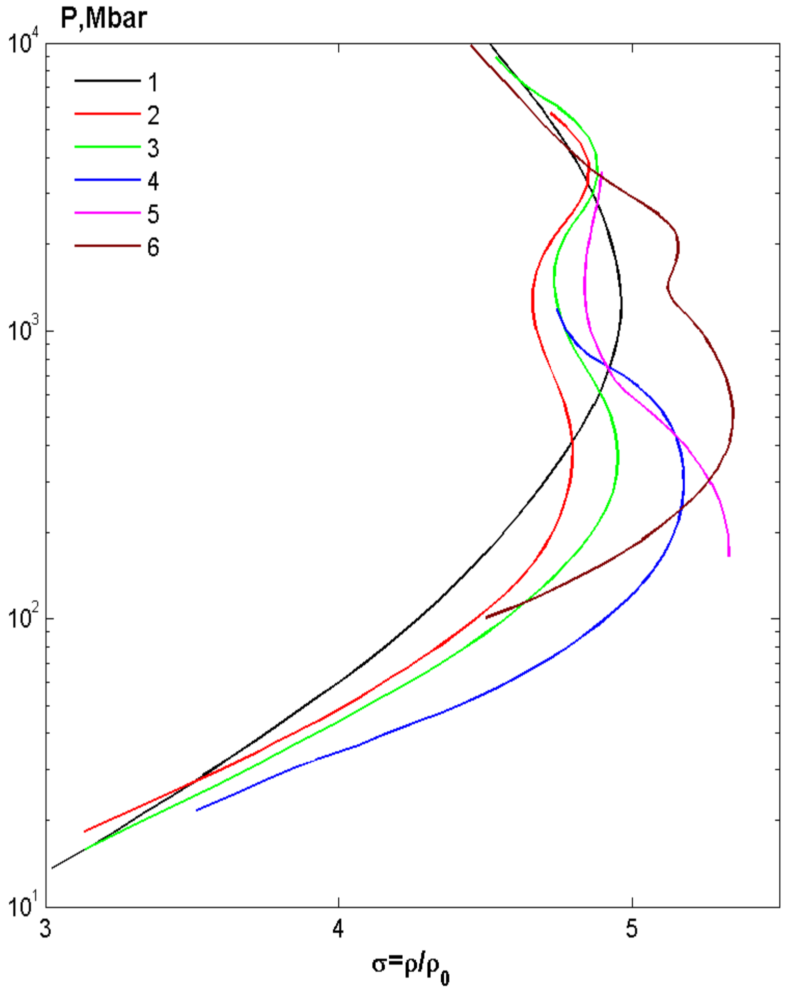


Contact and light measurements

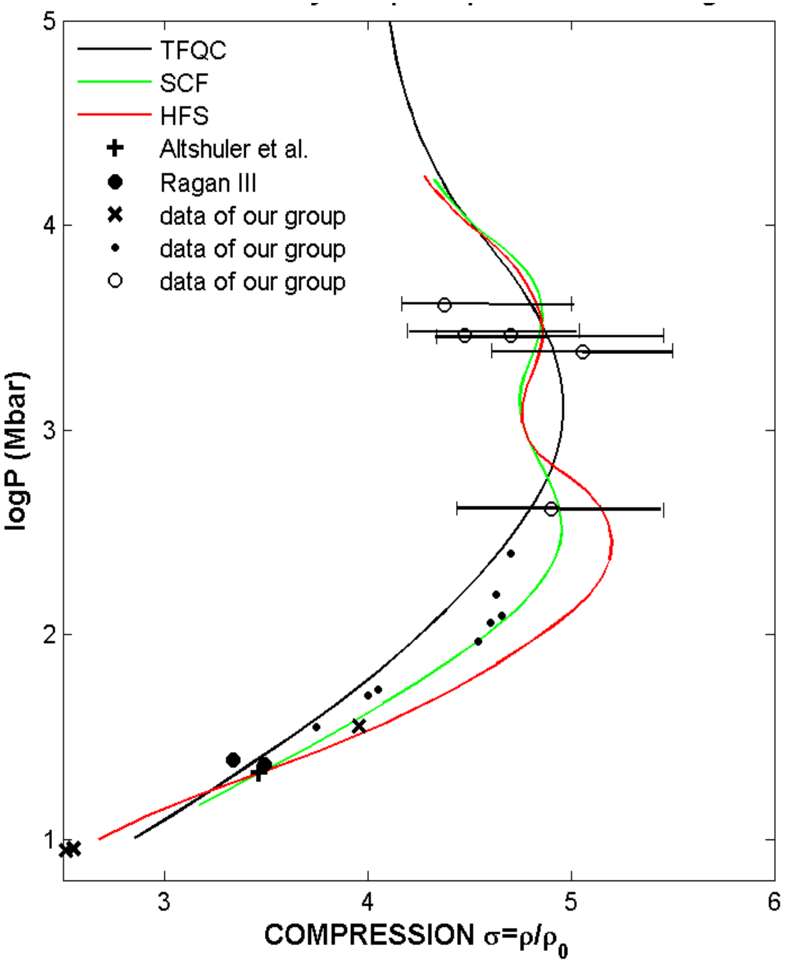




Normal Al Hugoniot

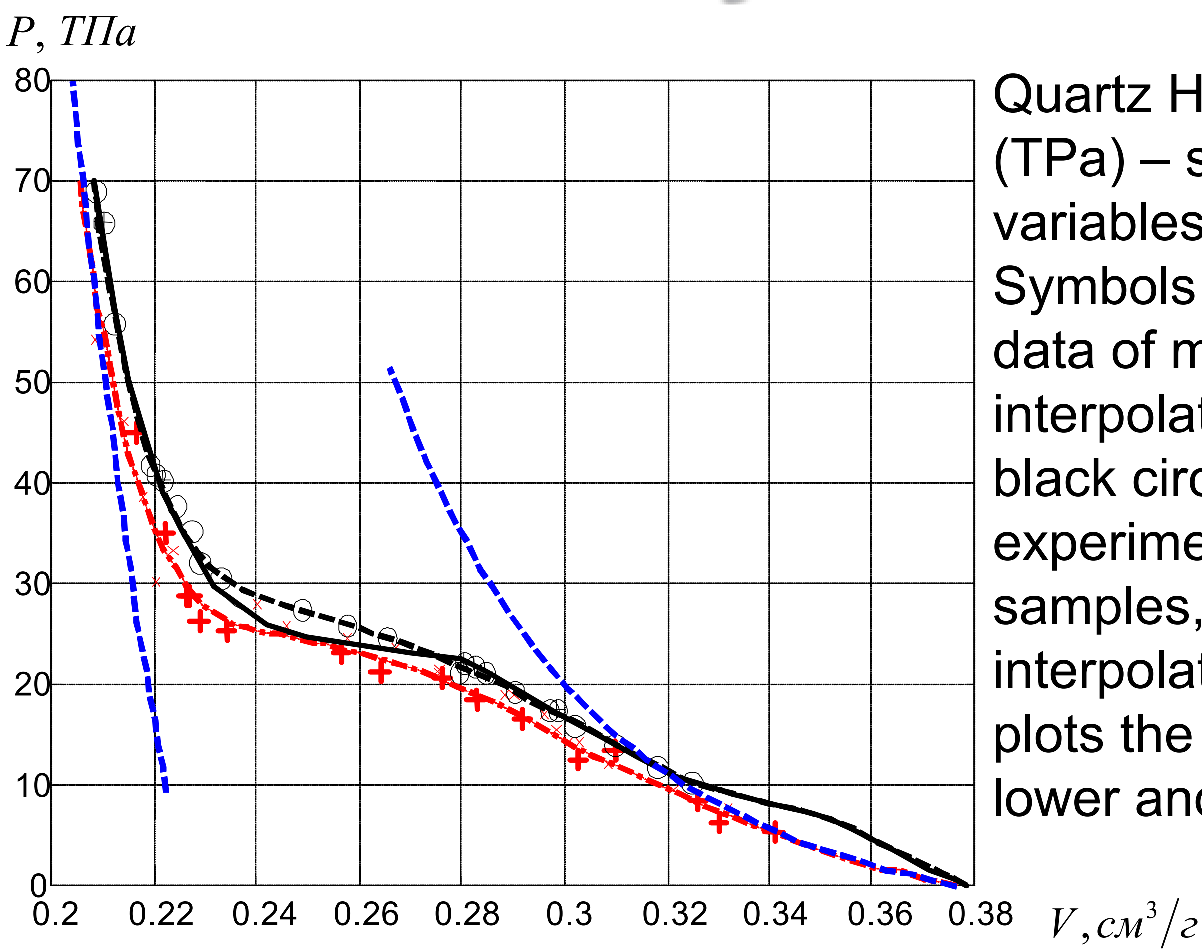


Comparison of theoretical models
1 – ТФПК, 2 – КУРС, 3 – ССП,
4 – МХФС, 5 – ACTEX , 6 – INFERNO.



Summarized experimental data and theoretical Hugoniots.

Quartz-stishovite transition under dynamic loading



Quartz Hugoniot in pressure (TPa) – specific volume *V* (cm^3/g) variables.
Symbols + and × correspond to data of mixture experiments, their interpolation is shown in red; black circles stand for experimental data with solid samples, the black curve is their interpolation; the blue dashed line plots the equation of state of the lower and the upper phases.

Prevention of asteroid collision with the Earth by nuclear explosions

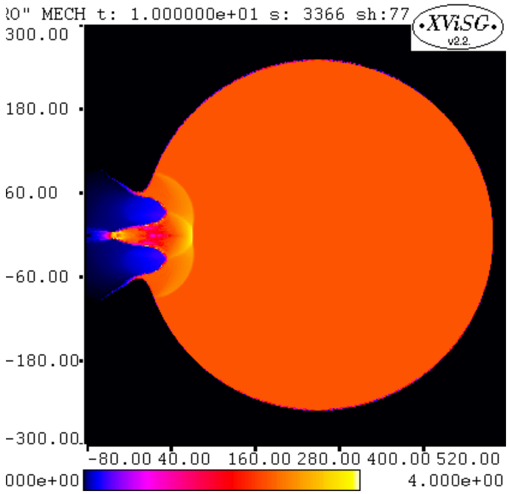
The following has been studied:

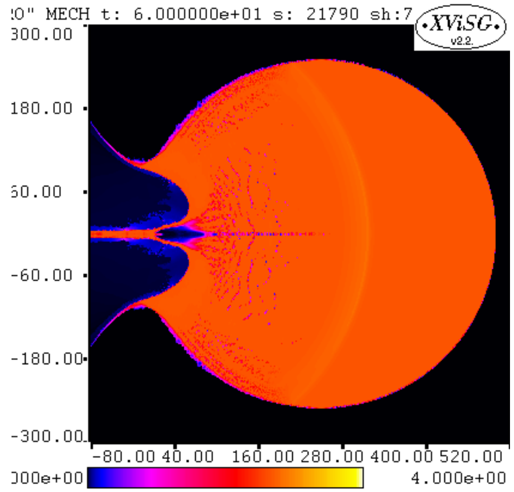
- **Velocity fields**
- **Fragment sized**
- **Scatter of evaporated material**

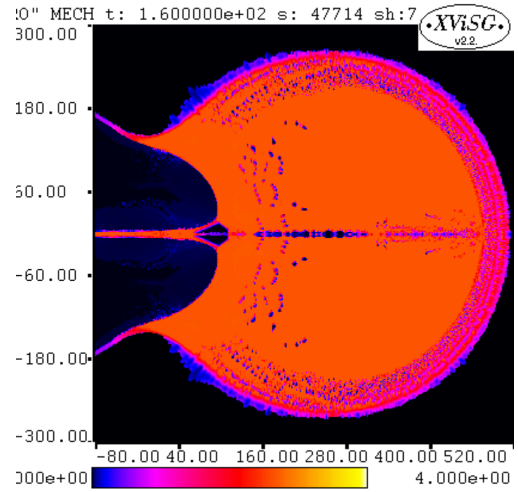
Object dispersion

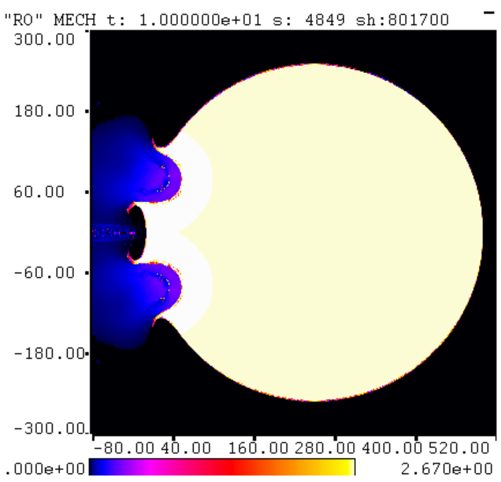
1. **R=50m (of Tunguska meteorite) by a single explosion with E=10 kt, 100 kt and 1 Mt, and 10 explosions of10kt.**
2. **R=250m by 10 explosions with E=100 kt and 1 Mt.**

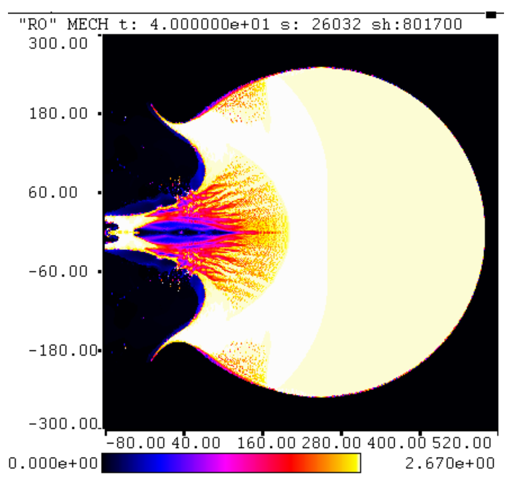
R=250m, E=100kt x 10 and E=1Mt x 10

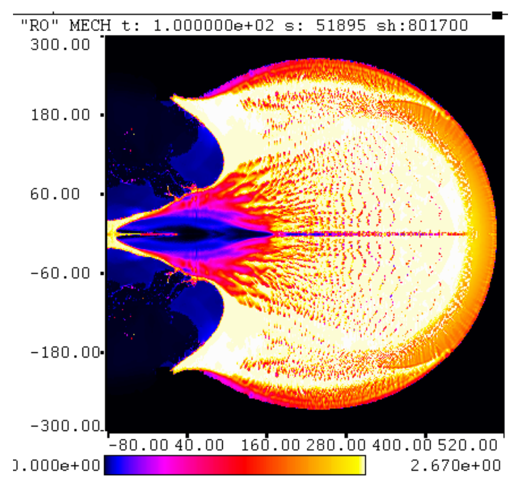




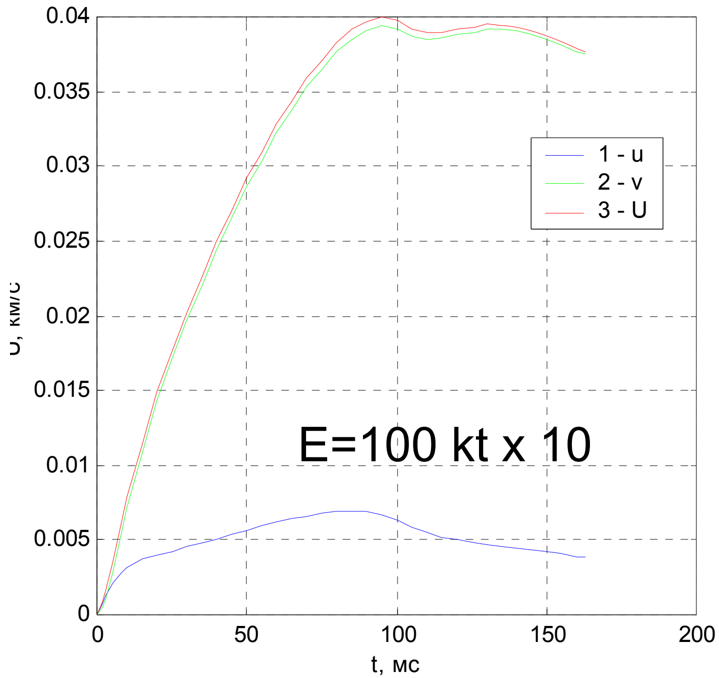


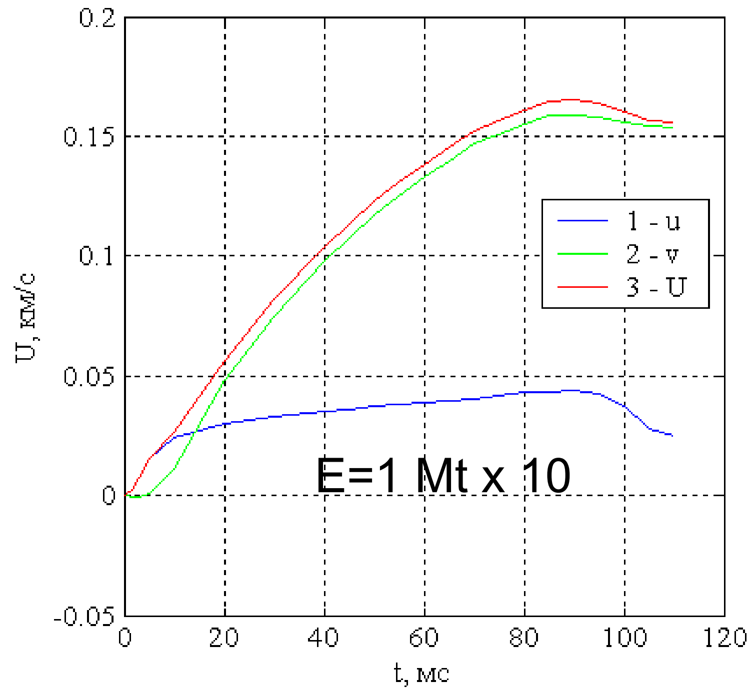






Dispersion velocities

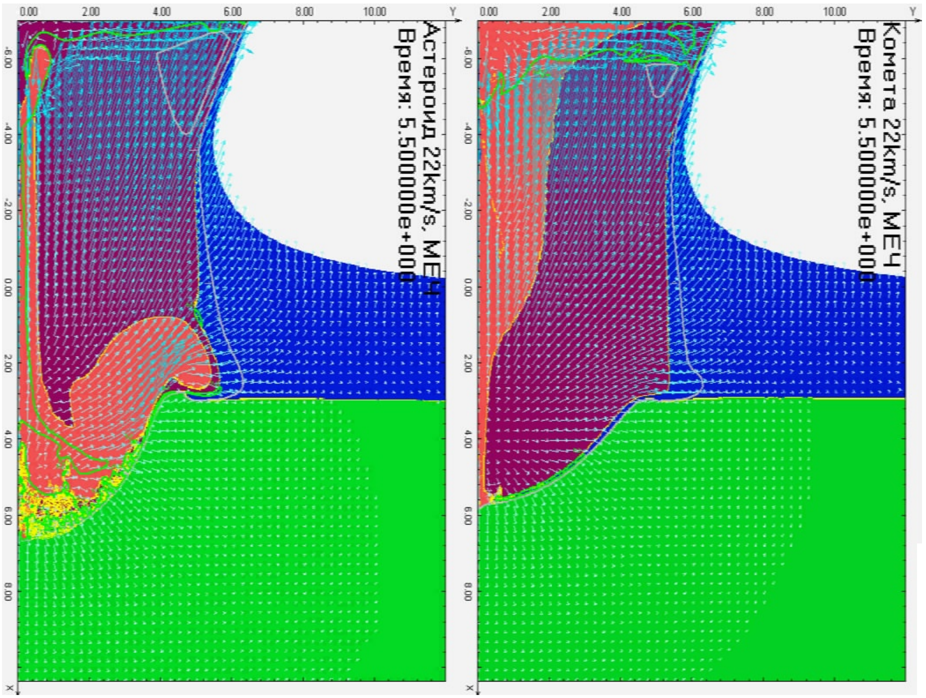




Megacumulative processes in dissipative media

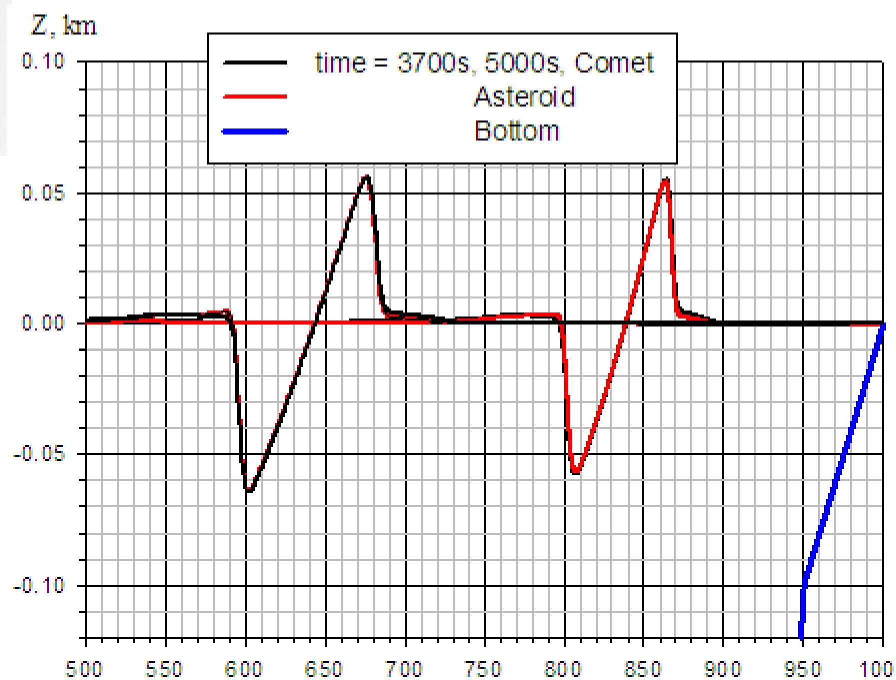
1. *In planetary conditions.*
2. *In stellar systems.*

Falling of an asteroid or a comet into the ocean



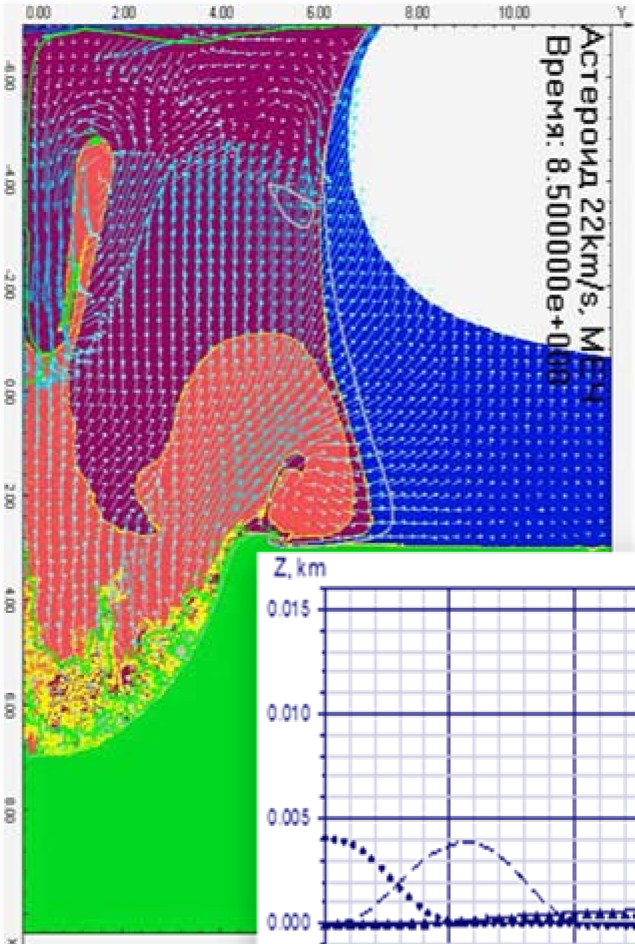
- *Vertical falling of a stone asteroid or an ice comet of the same mass into the ocean to the depth of 3 km. Velocity – 22 km/s. Ocean bed rocks are similar to granite. The asteroid diameter is 1 km. Characteristic time of processes in the vicinity of the impact is ~ 1s, whereas tsunami propagation time in the ocean is thousands of seconds.*

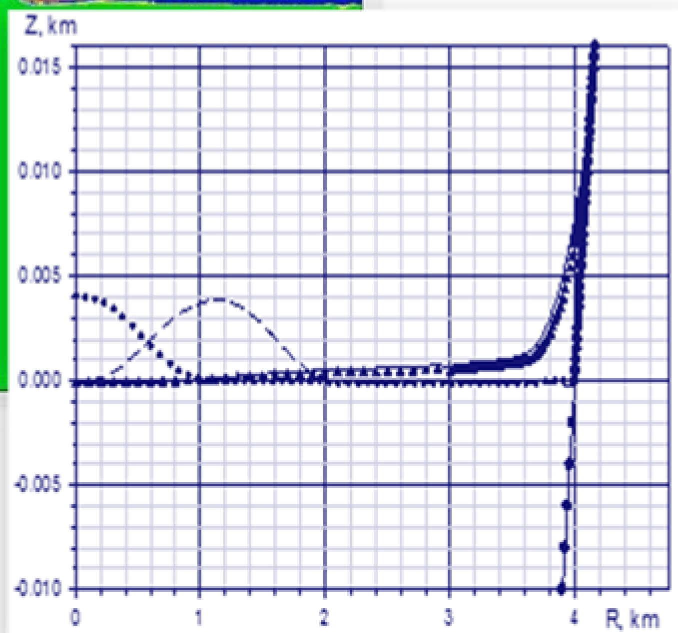
Two moments of time: wave arrival to the shelf beginning and to the salient point at the shelf profile. Wave height is 54 m. Wave profiles are practically imperceptible.

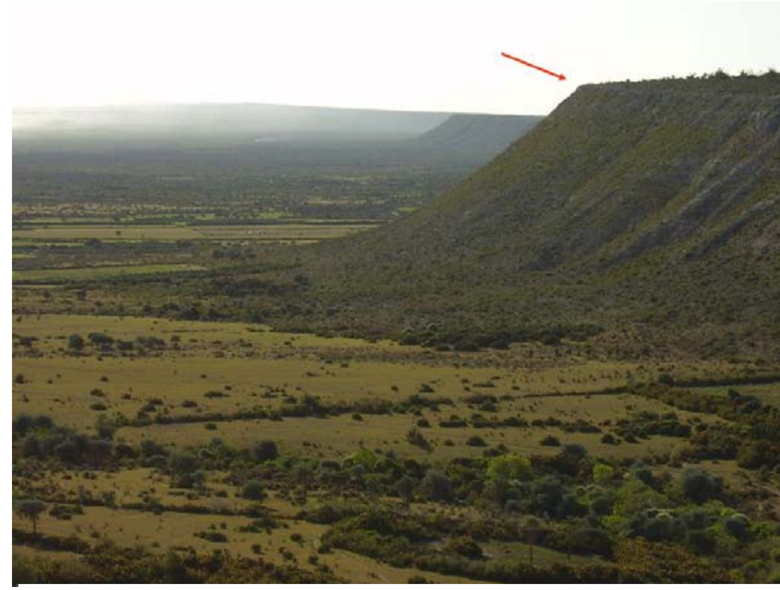


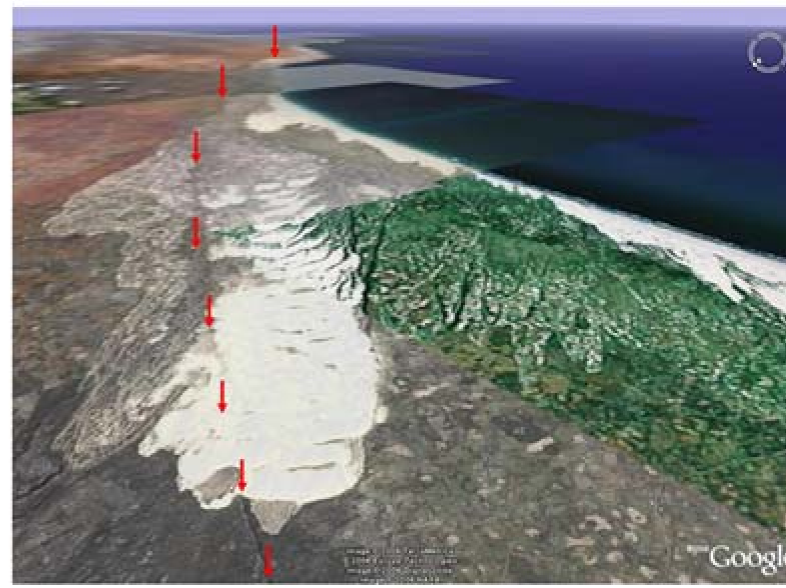
V.A. Simonenko, V.P. Elsukov, N.A. Skorkin, T.A. Ivankova, S.G. Kutepova, A.S. Uglov, S. Yu. Filatov, ***Numerical Simulation of Tsunami Caused by Falling Asteroids and Comets, ZST abstracts 2007, p. 17..***

Tsunami wave



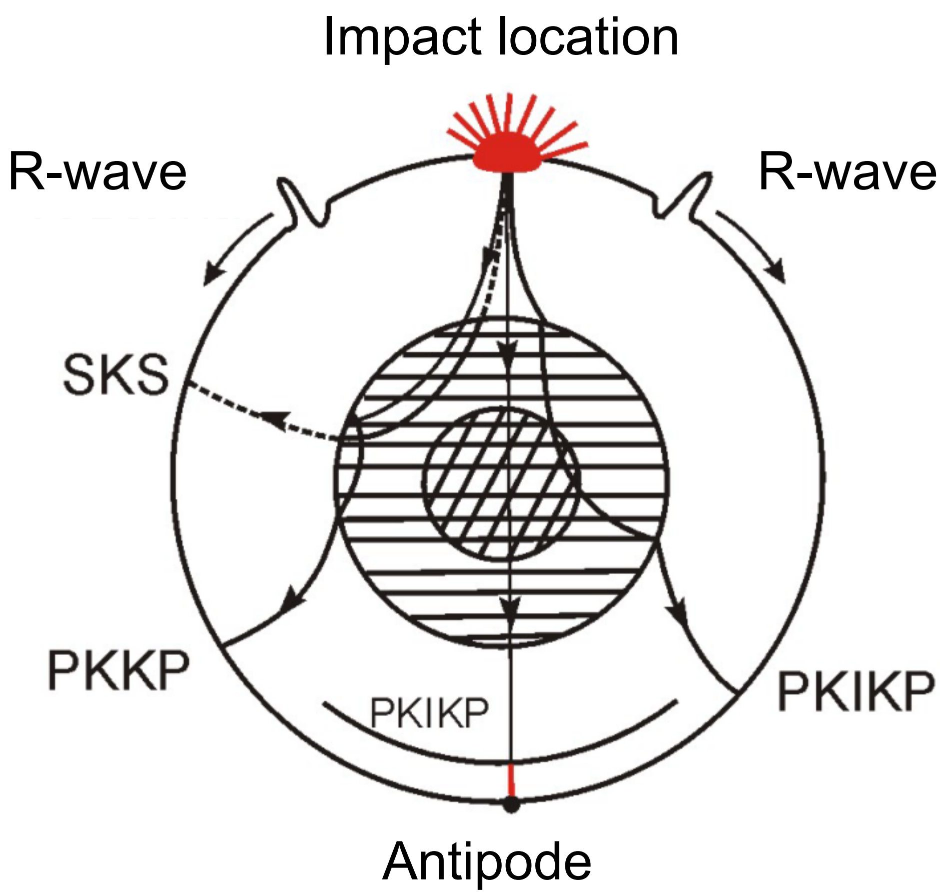






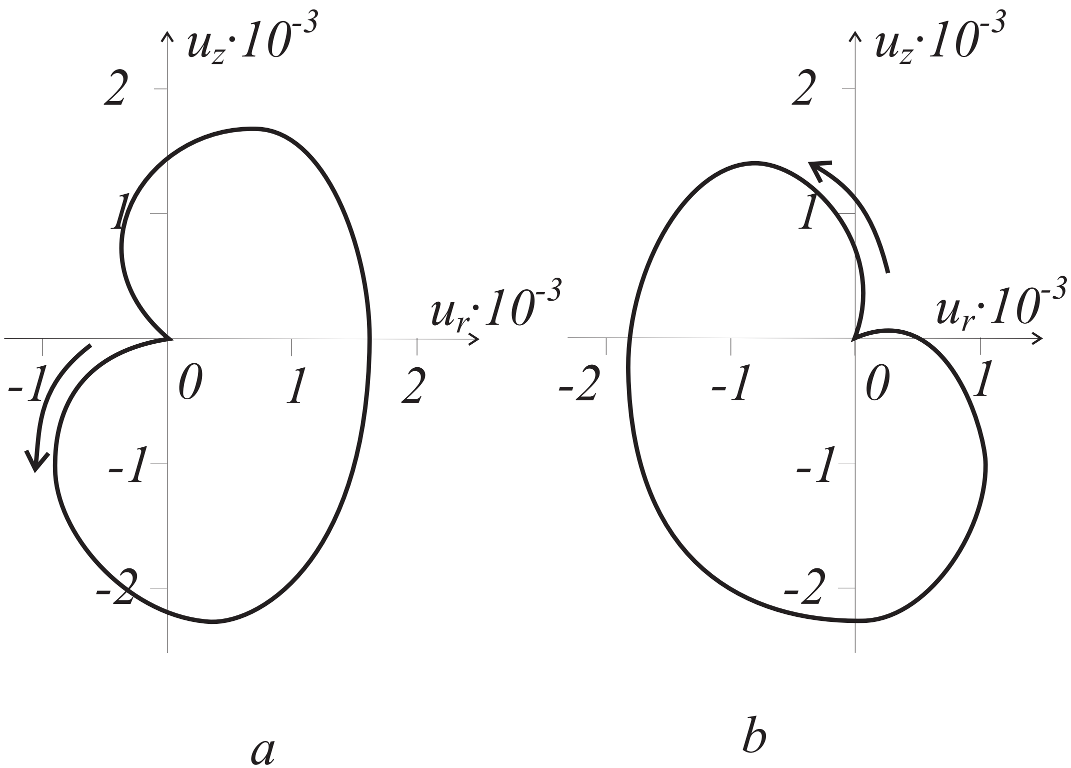
Chevron dunes of Madagascar

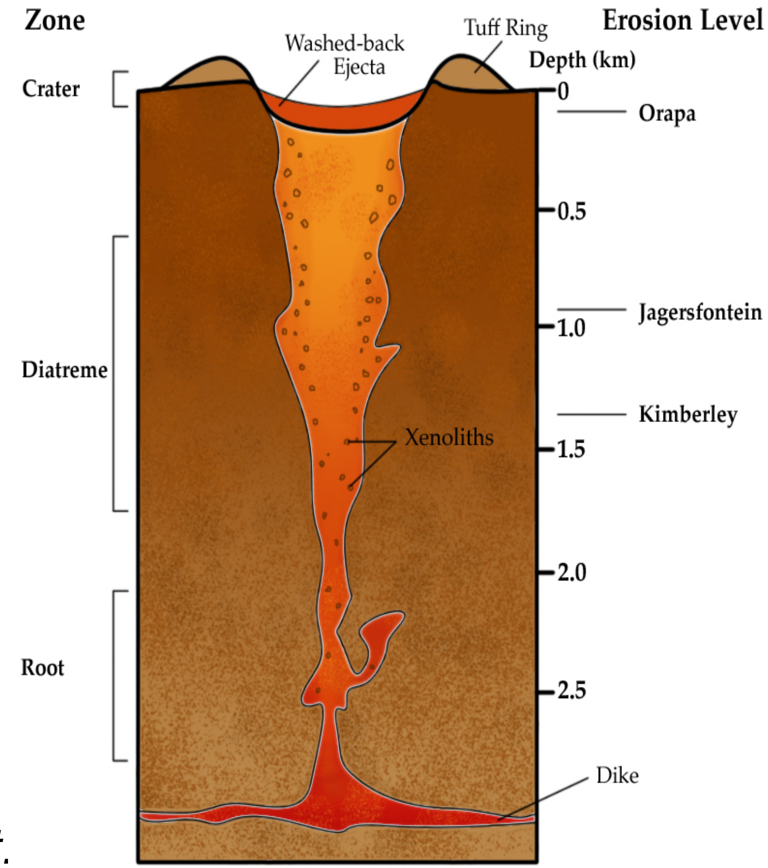
Hazardous Space object impact the Earth surface. Rayleigh wave focusing.



- Focusing of Rayleigh waves of collisions origin in the antipode at the planet surface.
- Either a diatreme field or kimberlite pipe is formed in the focusing region.

Impact theory of explosion tubes.

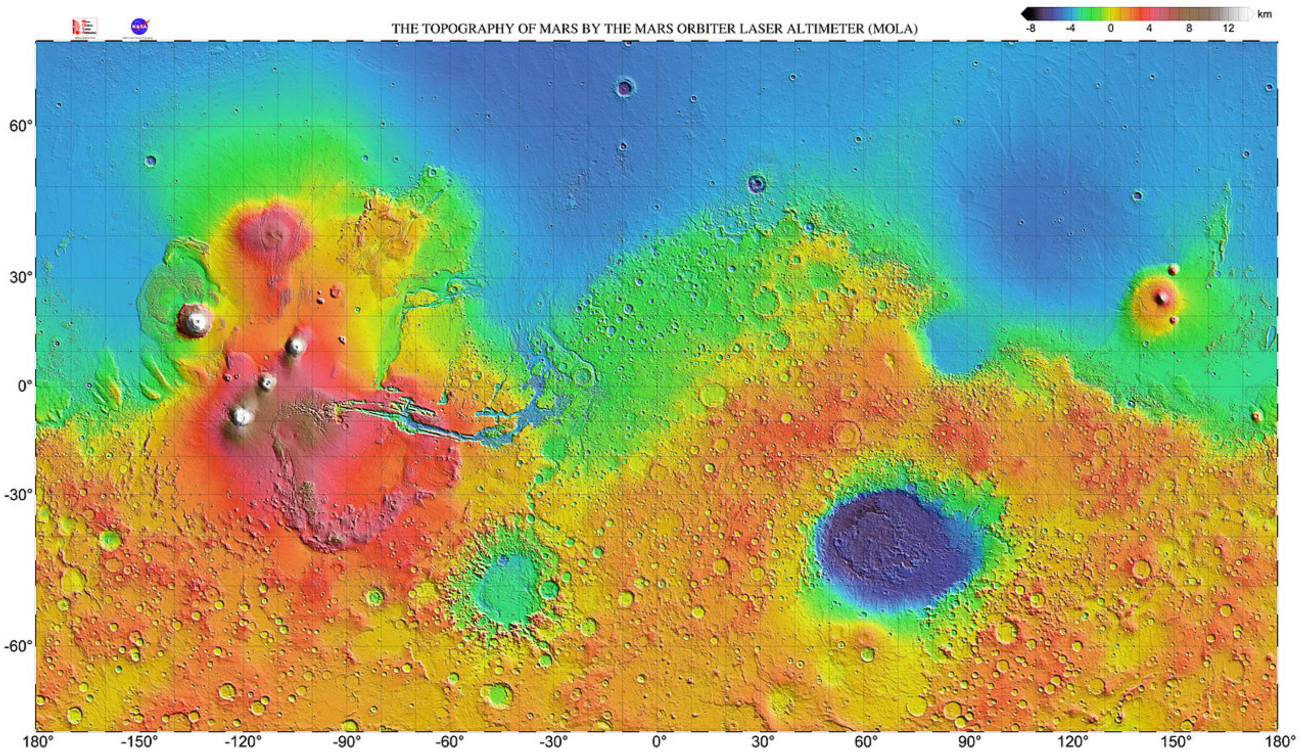




Phase change of particle movement phases at a conventional equator in relation to the impact point.

V.A. Simonenko, N.I. Shishkin, The role of seismic wave cumulation in the process of kimberlite pipe formation. PMTF, 44, #6, 2003.

Focusing of bulk waves?



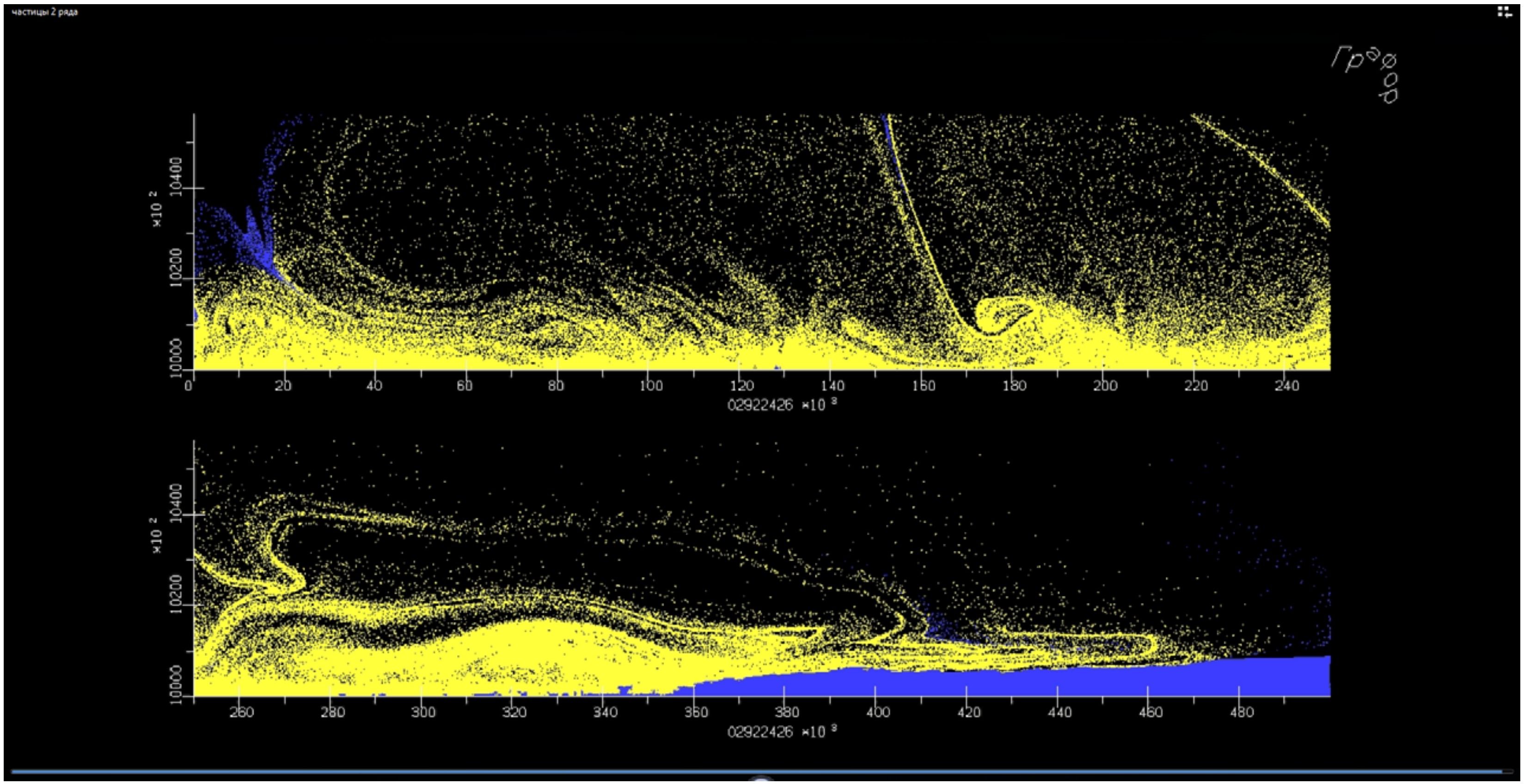
Are basaltic outpourings related to shock craters?

1. **Hellas Planitia** (-7km)
2. **Petera Alba** (+6,8 km as related to the average surface level)

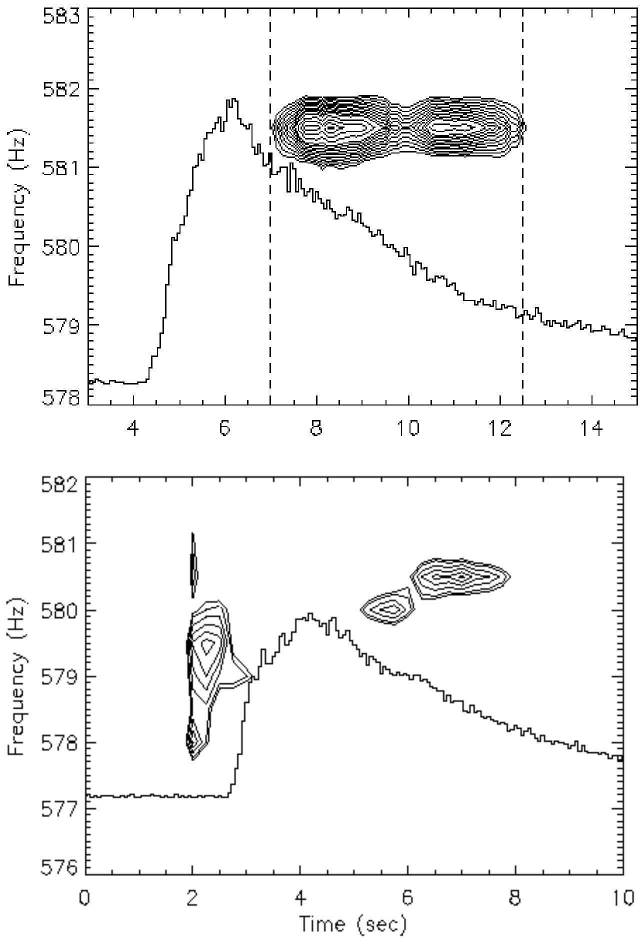
Dissipative cumulation in astrophysics

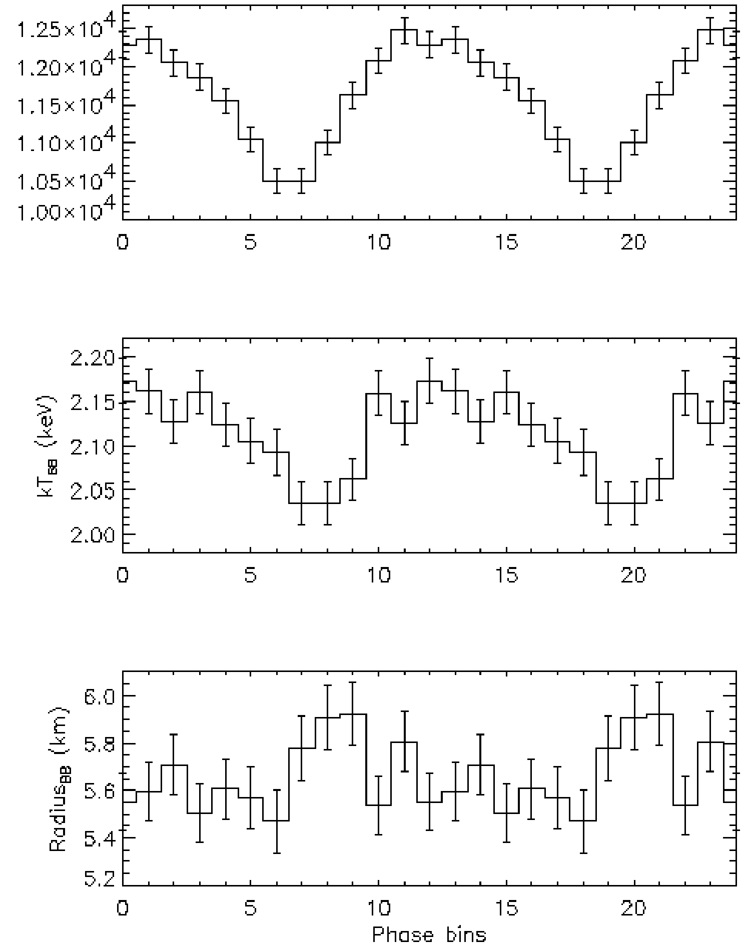
1. In 1965 E.I. Zababakhin considered cumulative processes at supernova explosion.
2. From this viewpoint, star formation from a protostar cloud and planet formation from a protoplanetary material are cumulative processes, star evolution.
3. Arrival of a shock wave at the surface of the atmosphere. Formation of cosmic rays.
4. Tight binary systems. Matter accretion from a common star to a neutron star (NS). Deposition and evolution of the accumulated matter into the NS atmosphere.

Thermonuclear flashes at the surface of neutron stars



4U 1636-54





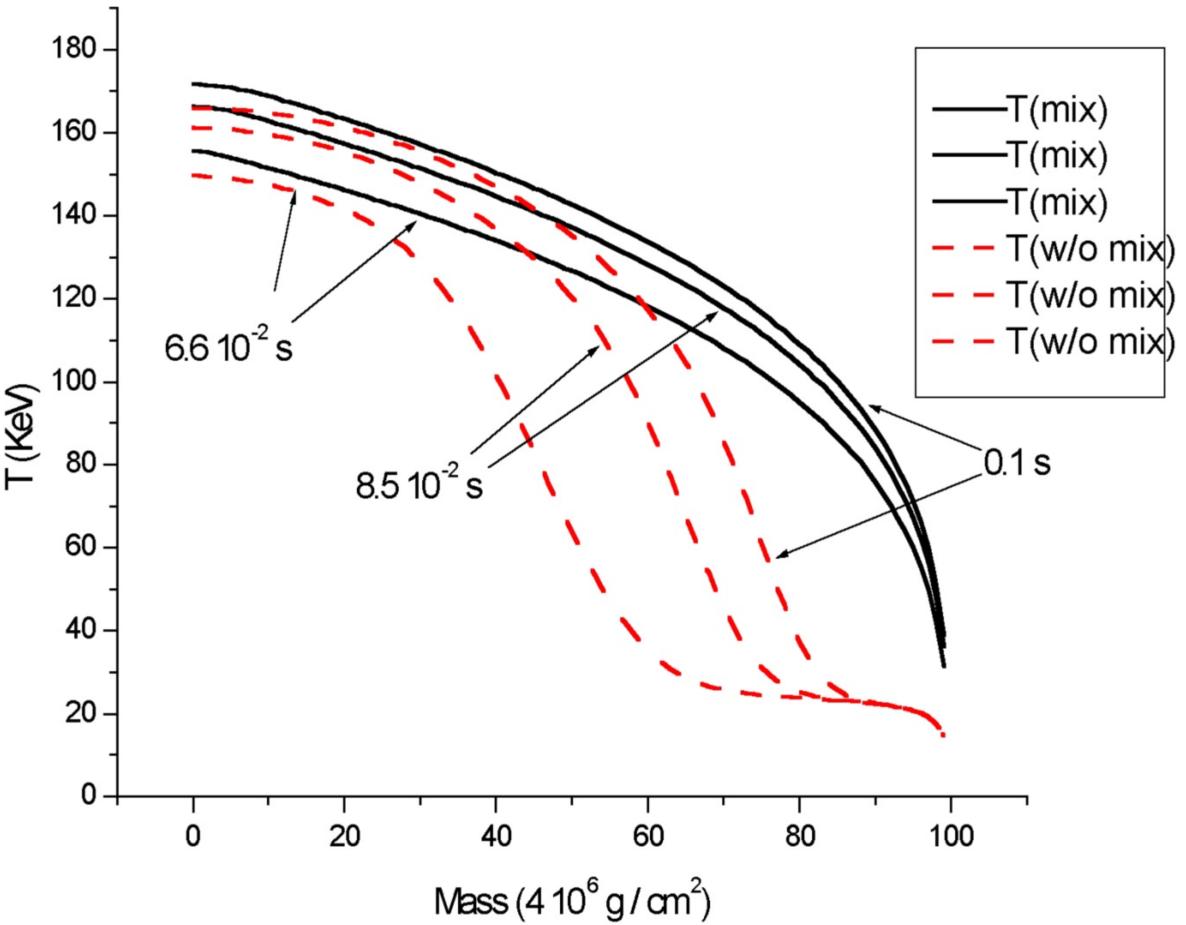
Brightness oscillations of two flashes. On the left – signal shapes, on the right – count rate, temperature and radius.

Strohmayer et al 1998, *ApJ* **498**, L135.

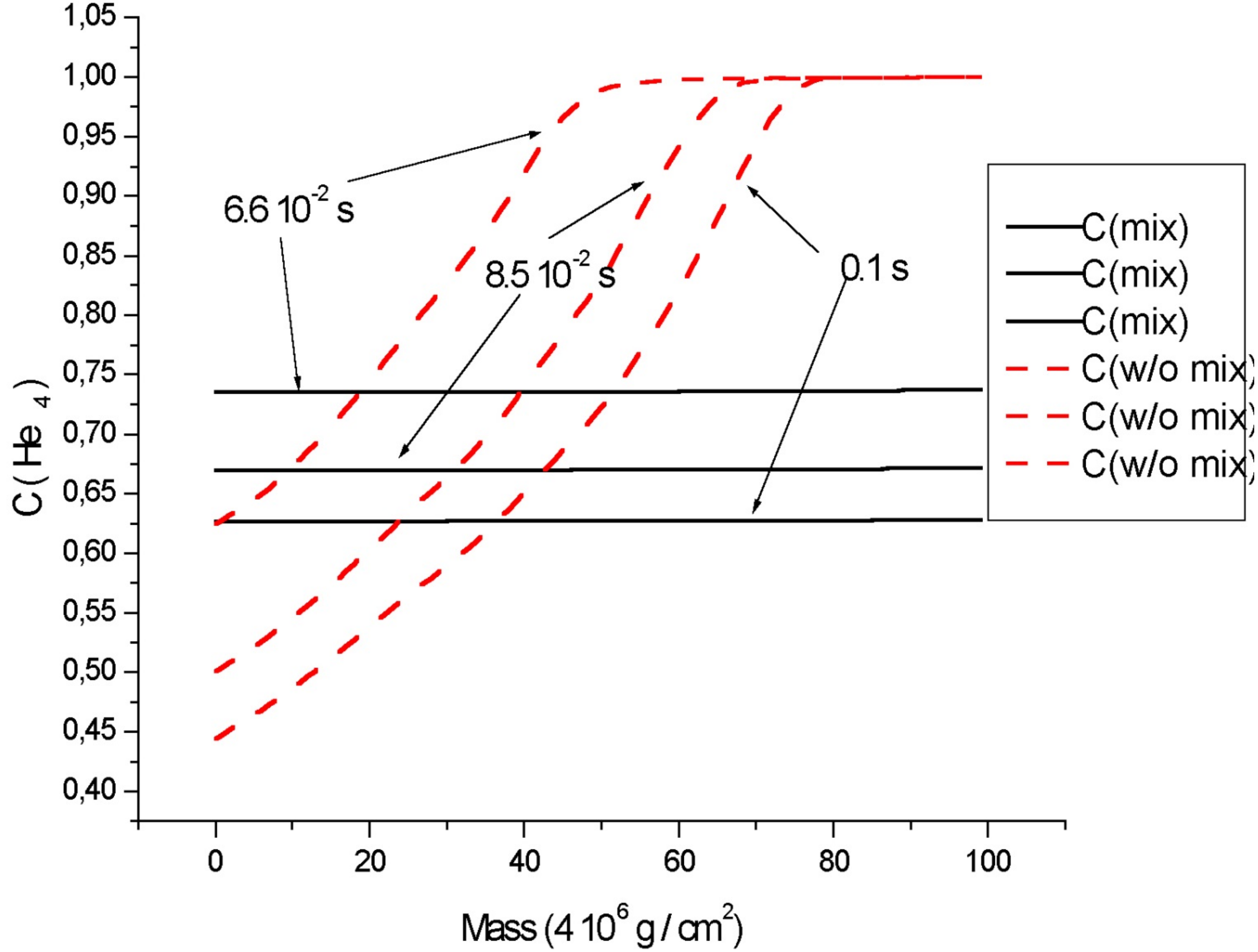
Thermonuclear flashes at the surface of neutron stars

Sources	Oscillation frequency (Hz)	Quasi periodic oscillations splitting (Hz)
KS 1731-26	524	260
4U 1728-34	363	363 – 280
Galactic Center	589	Unknown
4U 1636-53	580, 290	276 – 251
Aql X-1	549	Unknown
4U 1702-429	330	330
X1658-298	567	Unknown
4U 1916-053	270	290 – 348
4U 1608-52	619	312
SAX J1808-365	401	200
SAX J1750-290	601	Unknown

Temperature profiles



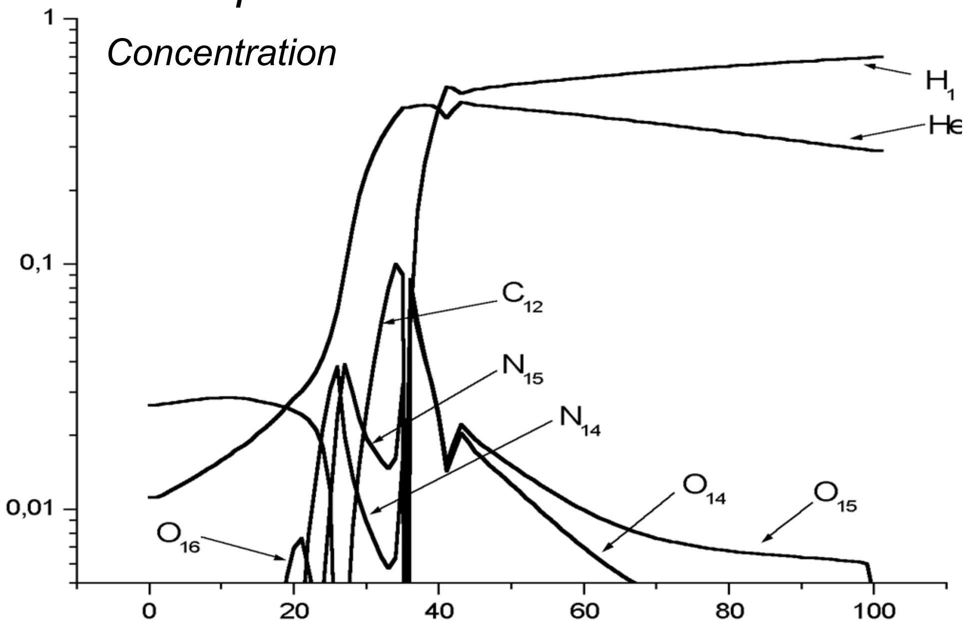
Helium concentration



Evolution of NS atmosphere composition at accretion of matter of a satellite star

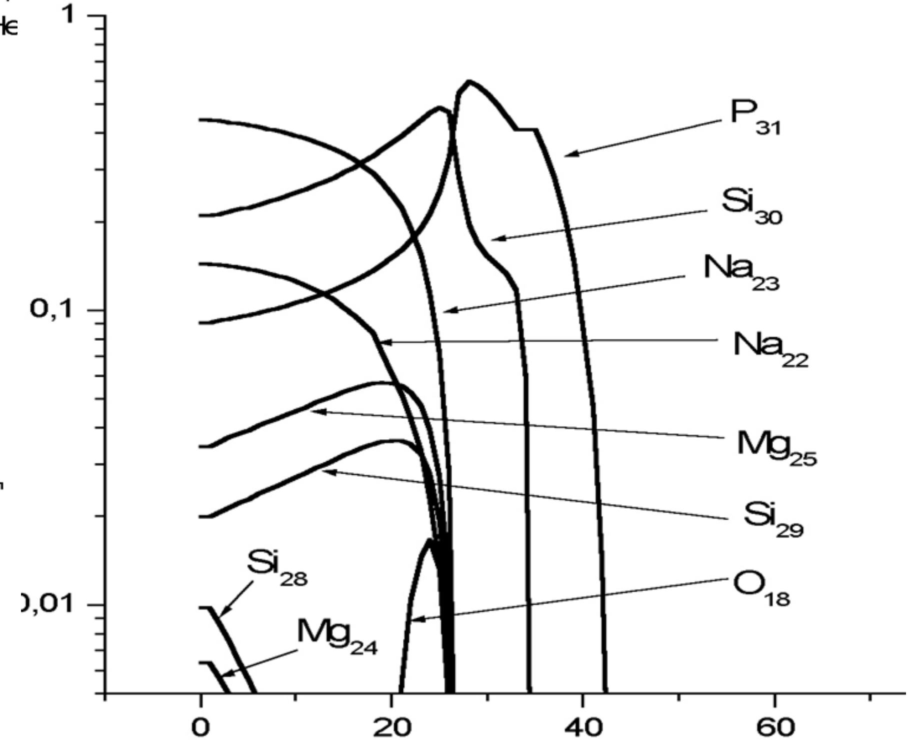
Quasistationary cumulation in dissipative media and in external power field.
The mode of picnonuclear reactions (density $\backsim 10^7$ g/cm^3)

Composition before TN He^4 flash



Relative depth
(layer mass in %
of NS atmosphere mass.

Composition after TN He^4 flash



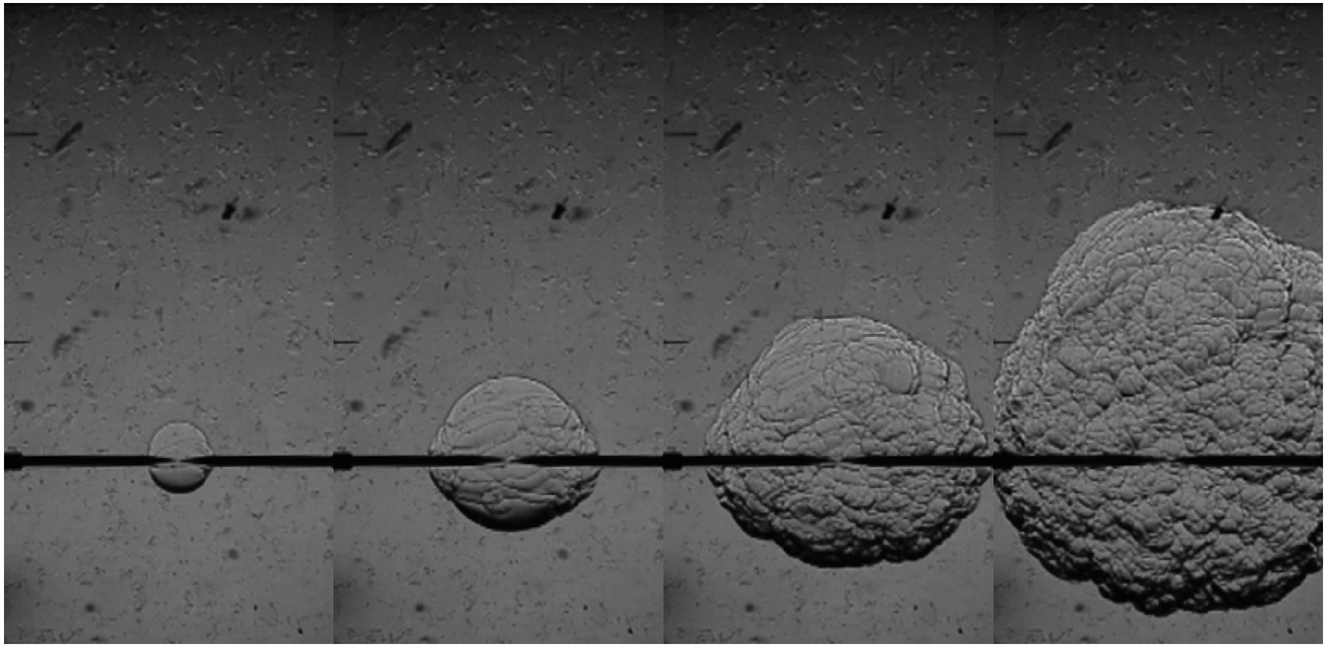
Microcumulative phenomena

1. *Flame front at laminar combustion*
2. *Single-bubble sonoluminescence*
3. *Resonance collapse of a bubble cluster in deuterated acetone*
4. *Wakefield at focusing of a femptosecond laser beam*
5. *Горение в регулярной гетерогенной системе*

Flame front at laminar combustion

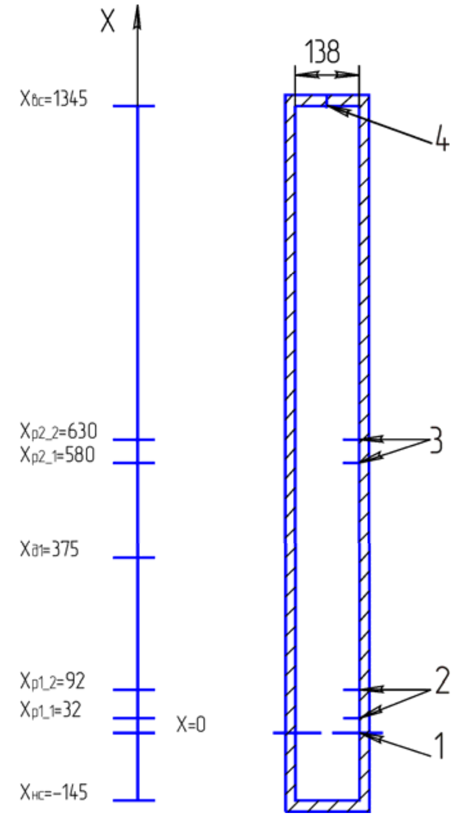
1. Energy cumulation in the flame front at laminar combustion is determined by a strong dependence of energy release rate on temperature.
2. The uniqueness of this process is that it is generally controlled by heat conductivity of the media and diffusion of reagents.
3. At the increase of reagent concentration, a number of instabilities develops that distort the front. However, the flame laminarity is locally preserved for a long time.
4. At considerably high concentrations during combustion development, chaotic gas-dynamic component before the front is intensified. This results in the so-called bubble combustion mode.
5. Further development of the process results in transition of the combustion wave into the detonation wave mode.

Combustion wave

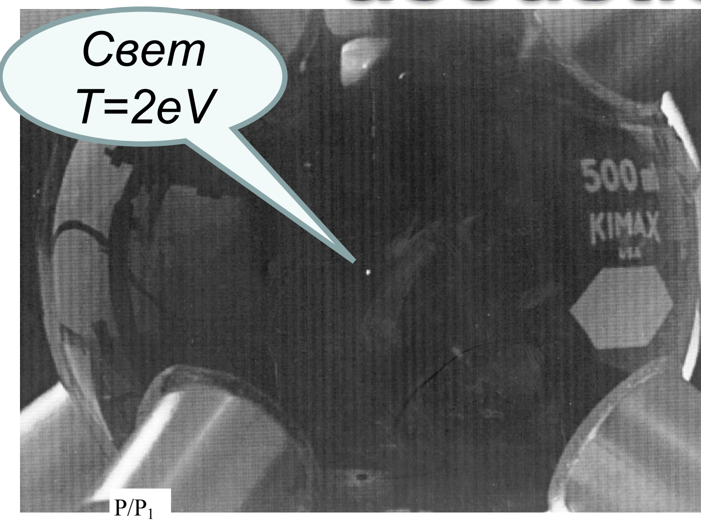


а) 5 мс б) 10 мс в) 15 мс г) 20 мс

а) 60 мс а) 67,5 мс а) 75 мс а) 82,5 мс



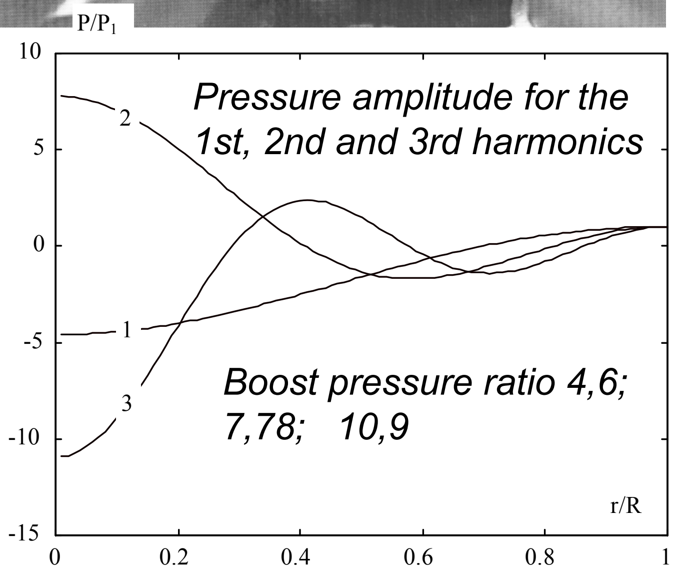
Microcumulation in resonance acoustic fields in a liquid

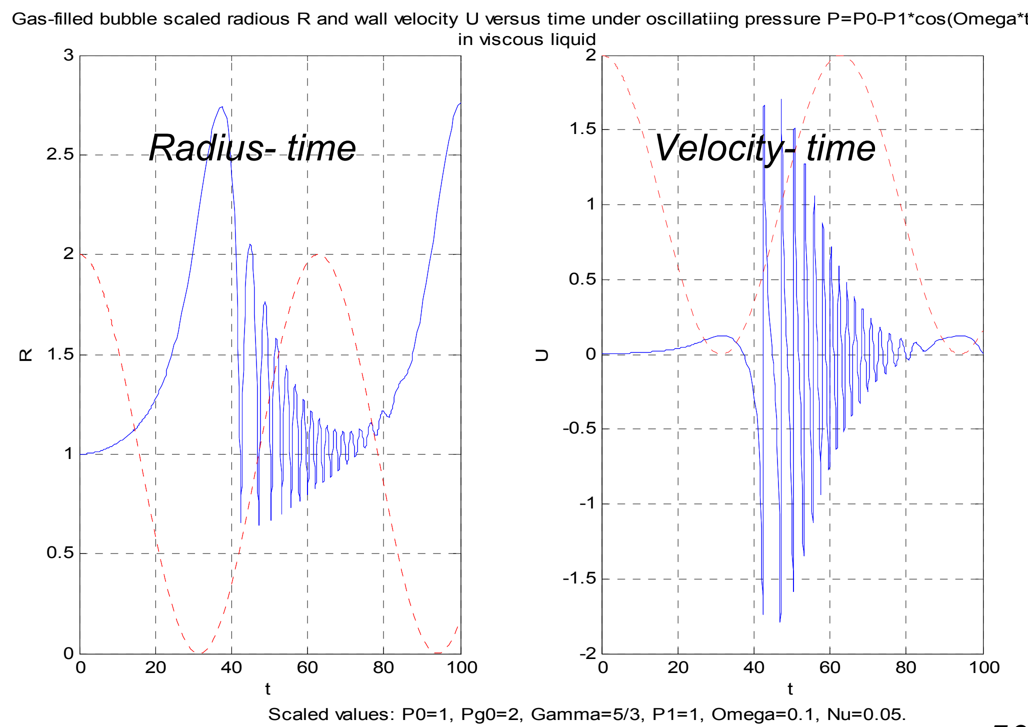


Single-bubble sonoluminescence

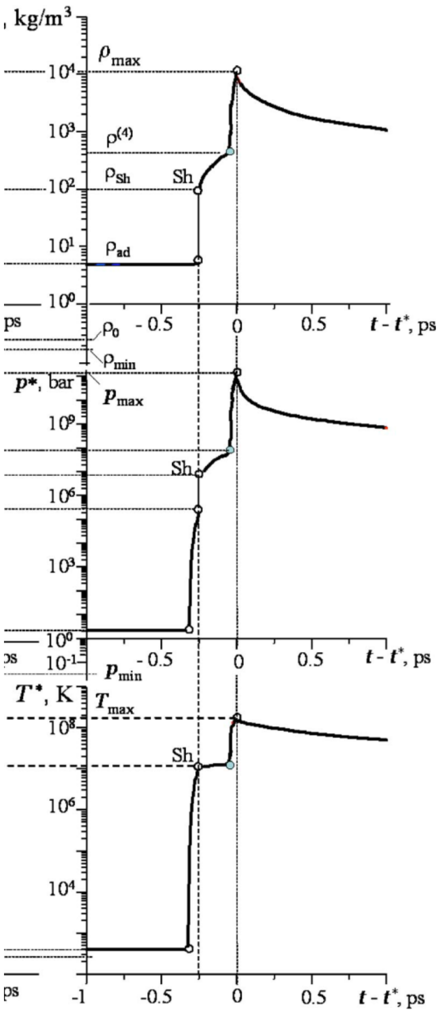
Increase of energy density in 10^{11} times

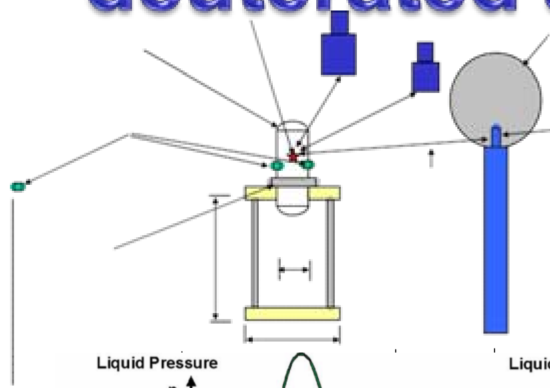
Gaitan, D.F., Crum, L.A., "Observation of sonoluminescence from a single, stable cavitation bubble in a water/glycerin mixture," Frontiers of Nonlinear Acoustics: 12th International Symposium on Nonlinear Acoustics, edited by M/ Hamilton and D., Blackstock (Elsevier, New York, 1990), pp. 459-463





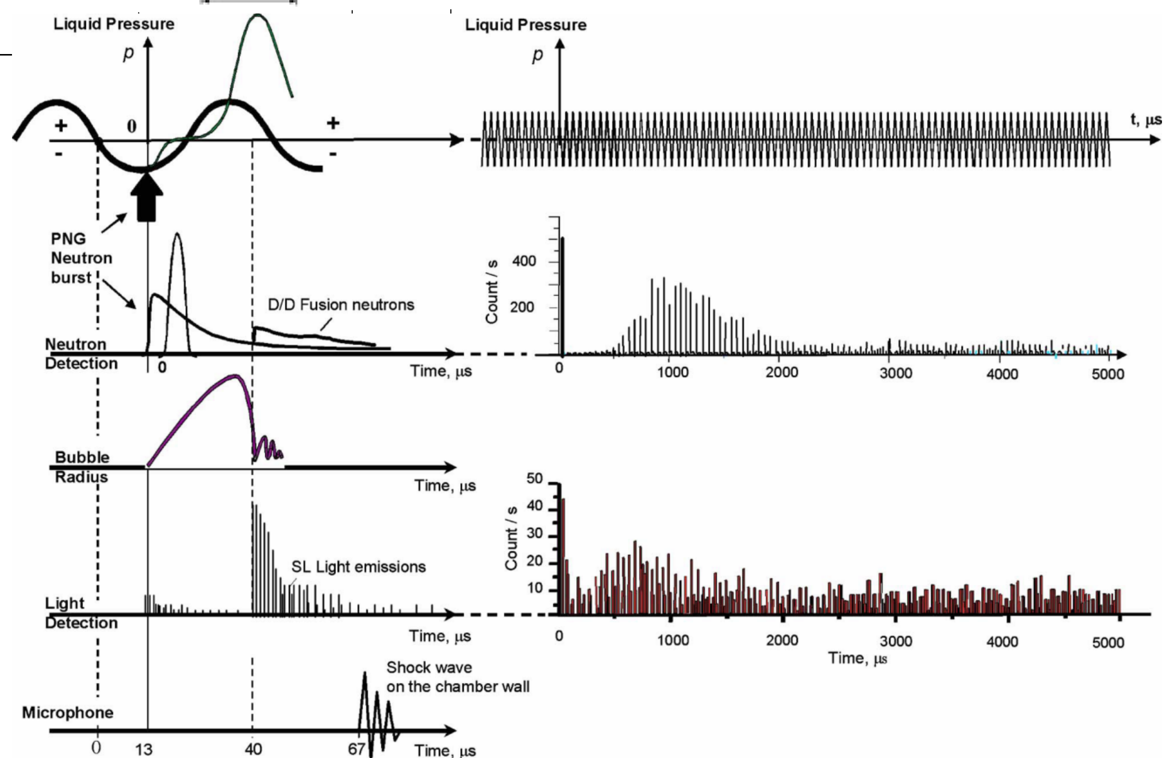
Resonance collapse of bubble cluster in deuterated acetone



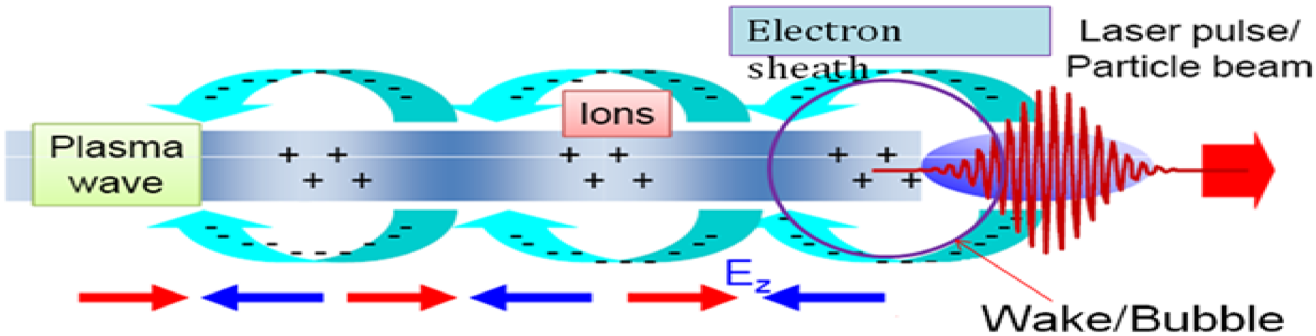


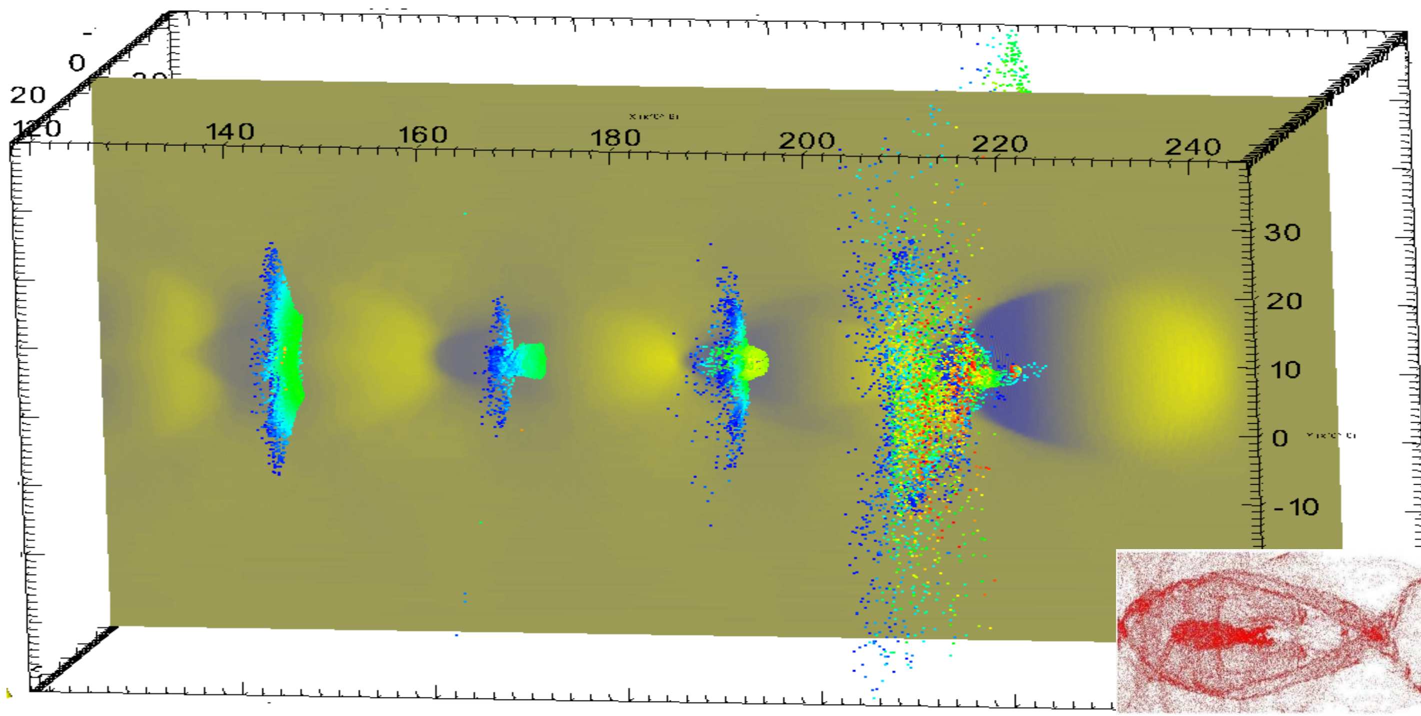
Nuclear Emissions During Self-Nucleated Acoustic Cavitation R. P. Taleyarkhan,1,* C. D. West,2,† R. T. Lahey, Jr.,3 R. I. Nigmatulin,4 R. C. Block,3,† and Y. Xu1

PRL **96, 034301 (2006)**

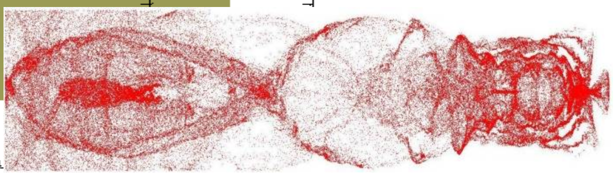


Wakefield at focusing of a femptosecond laser beam



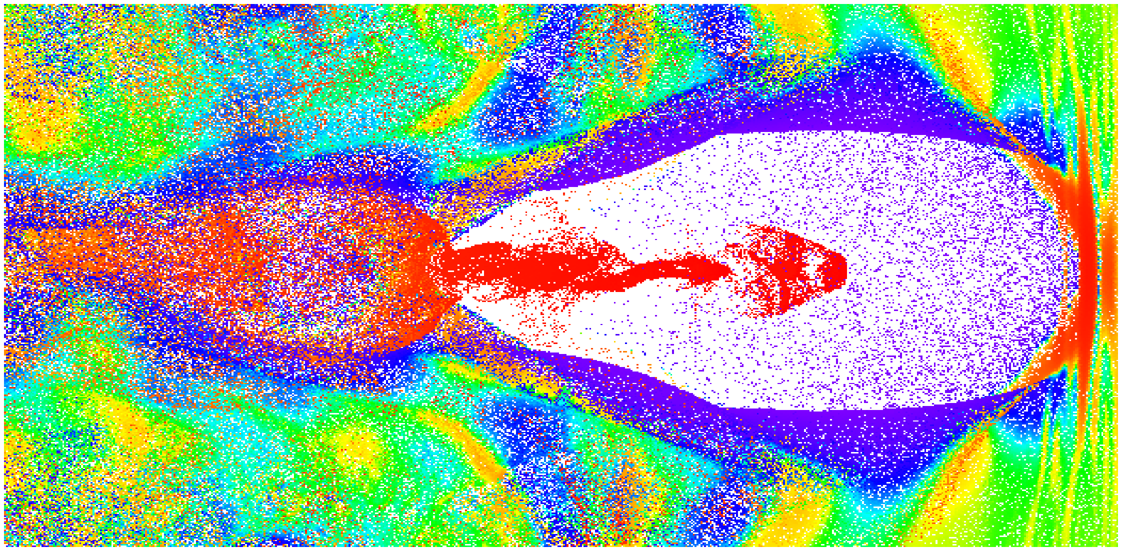


Simulation by Focus EM code



Appearance of cumulative processes

At femtosecond laser pulse impact on a target.

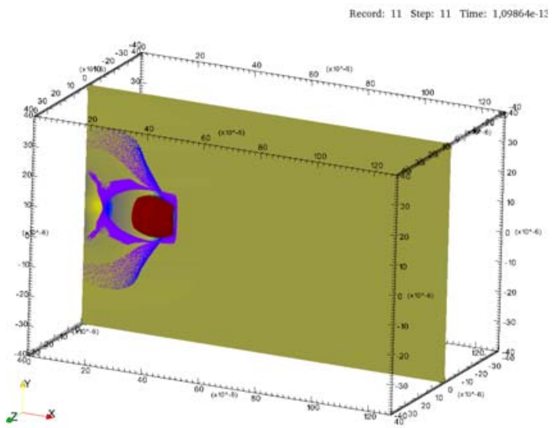


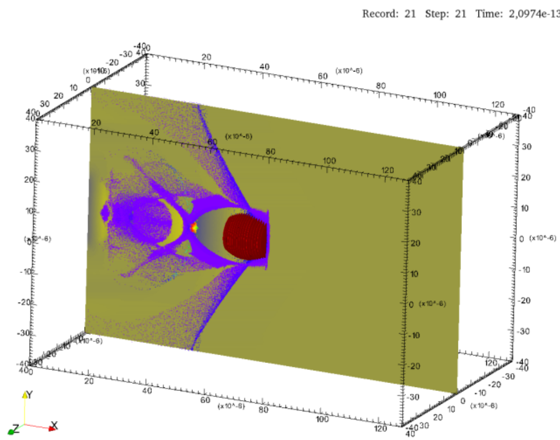
Plasma electrons are cumulated at the lend part of the vacuum structure.

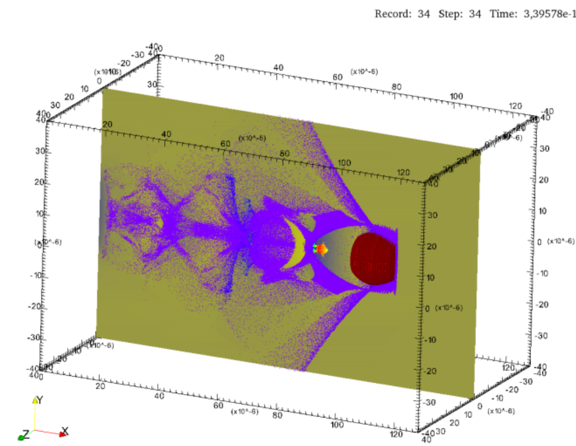
The flow is self-sustained, the size of cumulative jet depends on non-linear interaction of a laser pulse with plasma

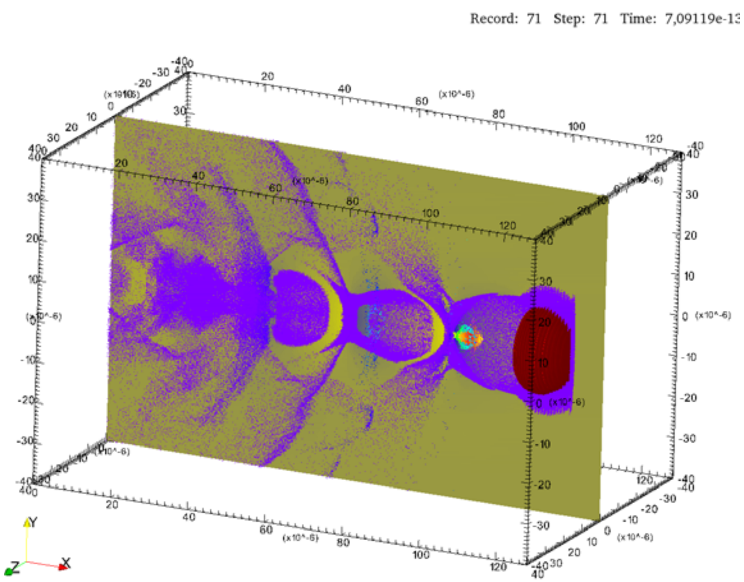
C. McGuffey, A.G.R. Thomas, W. Schumaker, T. Matsuoka, V. Chvykov, F.J. Dollar, G. Kalintchenko, V. Yanovsky, A. Maksimchuk, K. Krushelnick, V.Yu. Bychenkov, I.V. Glazyrin, and A.V Karpeev. PRL, 104, 025004 (2010)

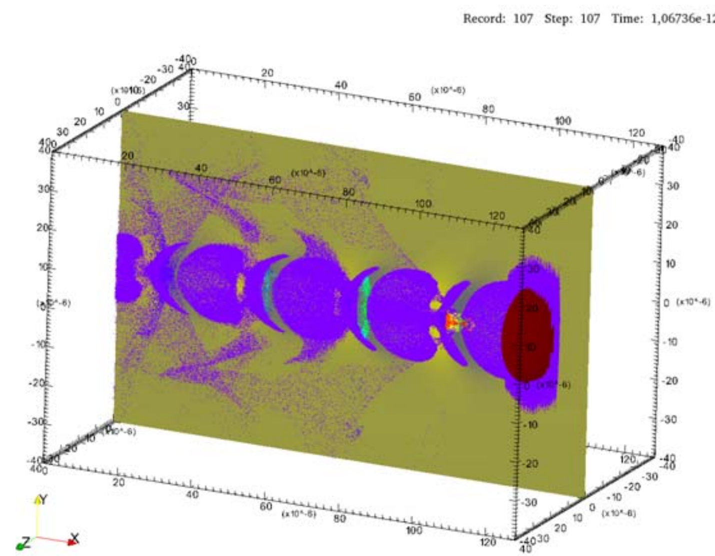
Wakefield


Record: 11 Step: 11 Time: 1,09864e-1


Record: 21 Step: 21 Time: 2,0974e-13

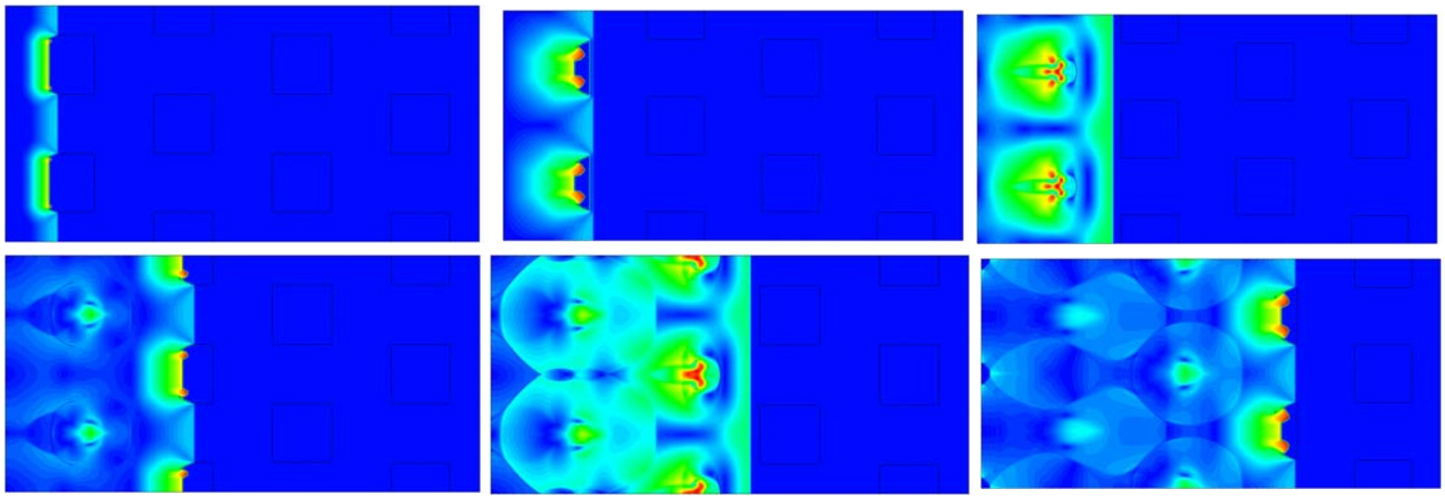

Record: 34 Step: 34 Time: 3,39578e-1


Record: 71 Step: 71 Time: 7,09119e-1

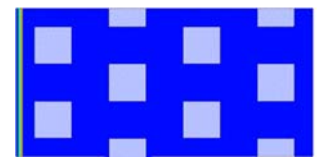

Record: 107 Step: 107 Time: 1,06736e-12

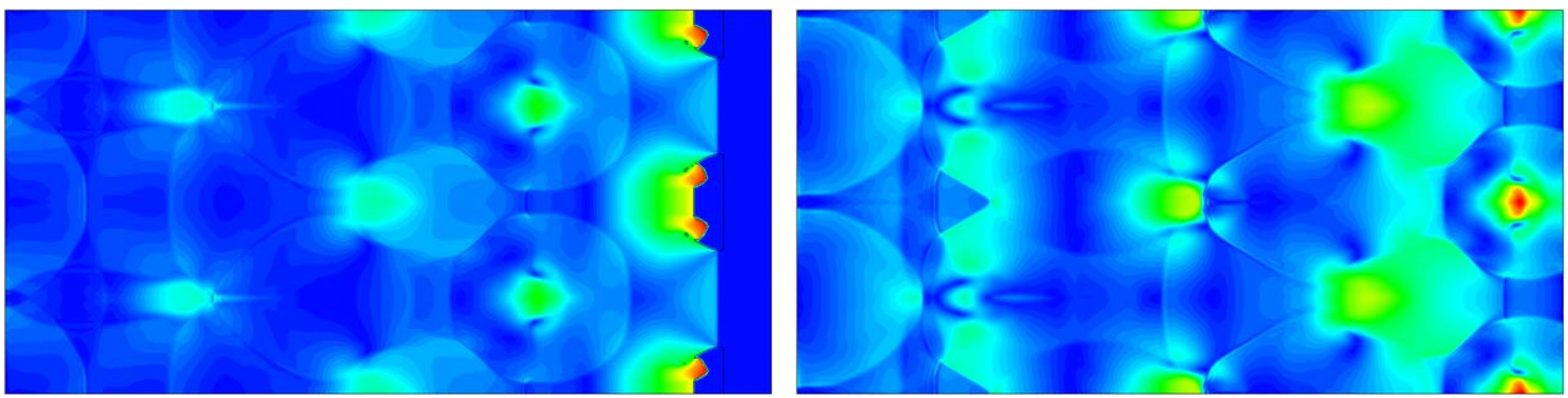
Burning in regular heterogeneous system

Burning at multiple coherent cumulative structures forms chaotic flow with low scale eddies structures



3D simulation by Phocus code





И.В. Глазырин и др. Доклад, ХНЧ-2016.

Conclusion

1. At the initial stage studies by E.I. Zababakhin had a tremendous impact on the choice of directions and the scope of research on high-intensity and cumulative phenomena.
2. Successful implementation of the initial statements promoted development of a profound theoretical and experimental support of these studies.
3. Due to E.I. Zababakhin's influence, establishment of a new center in the Urals fostered not only the continuation of research started in Sarov, but also profound expansion of these studies both in terms of properties and of cumulative processes, but also in terms of investigation into material properties in high-intensity processes.

4. Transition to techniques of conducting powerful explosions in dense media provided good opportunities to expand the research of high-intensity phenomena and the related material properties.

5. These studies have been conducted at direct support of E.I.Zababakhin and lead to results that are still in high demand.

6. E.I. Zababakhin also continued and supported work on expanding the research and applications of cumulative processes. In particular, theoretical work on sharp the loading pulse at adiabatic compression of targets, on the use of experiments with recovered spherical samples to study media properties after dynamic loading.

7.The insight into strong explosion phenomena in dense media promotes studies of hazardous collisions of asteroids and comets with the Earth and measures to prevent them.

8.New capabilities to study high-intense processes were opened by the use of powerful laser systems. We have almost omitted this powerful direction of research in our presentation. We provided a very rich in physical content examples of cumulative processes in a femtosecond pulse wakefield.

9. Interesting examples, record-breaking by the degree of energy concentration ($10^9 \div 10^{12}$), have been obtained at collapse of resonance acoustic waves in cavities filled with water and deuterated acetone.

10. In the last case additionally a bubble cluster has been created and neutrons of thermonuclear origin have been obtained.

11. The presented analysis, far from being complete, of the discussed direction shows, that research in this direction still tends to expand and open new and exciting possibilities.

Thank you for your attention!

Vishnyovaya (“Cherry”) mountain
March 11, 2017 г.