"Microgravity research on the ISS”
Through the eyes of a Scientist.

Valentina Shevtsova

Microgravity Research Center, Brussels University (ULB), Belgium

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Origin:
Service de Chimie Physique of the Ecole Polytechnique de Bruxelles, Université libre de Bruxelles
⇒ MRC created by Prof J.C. Legros in the eighties
◆ Fluid Physics
◆ Thermodynamics
◆ Heat transfer
Director: Prof. F. Dubois

Microgravity activities:
◆ Thanks to PRODEX, ESA and BELSPO: multiple µg experiments in PF, DT, sounding rockets, space shuttle, Foton, ISS

PromISS

VIDIL
(followed by DCMIX 1, 2 and 3)
How the fluids affected by gravity

On Earth fluids flow and occupy the shape of a container.

Two of fluid transport mechanisms, **sedimentation and convection**, dominate on Earth because they are driven by gravity.

There are other fluid transport mechanisms that are not as affected by gravity, among them: **diffusion, surface tension and vibration**. But on Earth they can be masked by gravitational effect.

The surface tension of water is great enough that an insect can rest on the surface.
Example of multi-user scientific facility: 
Glovebox

On the ISS equipment is placed in autonomous racks.

Glovebox is fully sealed and controlled environment, completely isolated from the rest of the Station. It shares nevertheless the weightlessness and g-jitters of orbit.

MSG is on the ISS since 2002.

Why Glove?

The ‘gloves’ are the access points through which astronauts can manipulate experiments.
Five experiments have been performed inside SODI: **IVIDIL, COLLOID, DCMIX1 and DCMIX2, DCMIX3.**

SODI multi-user is designed to be inserted in Glovebox ISS Matreshka.

**SODI / IVIDIL inside MSG on the ISS**

SODI was uploaded on the ISS 29 August 2009 with the experiment **IVIDIL (Influence of Vibrations on Diffusion in Liquids)**

Activation of IVIDIL was done on 5th October 2009

A drawback - the limited lifetime of Facilities in Space example the screws of the interferometers which were out of date.
Objectives of the IVIDIL experiment on the ISS

- To investigate the impact of vibrations (g-jitter) on the measured values of coefficients
- To perform measurements of diffusion and thermodiffusion coefficients in two binary mixtures with positive and negative Soret effect.
- To investigate vibration-induced convection.

Two cell arrays contained binary mixture of water-isopropanol

- The experiment should be executed in automatic regime
- Astronaut places set-up inside SODI and exchange flash disks
Soret effect (thermodiffusion) is the relative mass flow induced by a temperature gradient in fluid mixtures, which drives different components of the mixture to the different walls.

Mass flux:

\[ J = -\rho D \nabla c - \rho D'_T \nabla T \]

Soret coefficient:

\[ S_T = \frac{D'_T}{D} \]

Soret coefficient, \( S_T \), can be positive and negative. \( S_T > 0 \) when lighter liquid goes to the hot wall; \( S_T < 0 \) when lighter liquid goes to the cold wall (against gravity);
It was seen that common minor movements that are part of daily life aboard a space station did not affect the samples.

In the case of imposed vibrations with constant frequency and amplitude the convective flows were settled in the cells.

IVIDIL paved the road for the experiments in ternary mixtures.
DCMIX: mixtures of different origins

DCMIX1 - 2011/2012

THN-IBB-C12

Regular solution of hydrocarbons

Belgian PI

Curiosity driven DCMIX4

Polymer/fullerene solution in binary mixture of ordinary solvents

DCMIX2 - 2013/2014

Tol-Meth-Ch

Mixture with miscibility gap

DCMIX3 → 2016

Water-Ethanol-TEG

Associating mixture with high contrast of molecule size

The set, though limited, covers all comprehensive aspects of mass transport in liquids.
Progress on thermodiffusion and DCMIX

**DCMIX**: Diffusion and thermodiffusion coefficients in MIXtures

Before DCMIX, almost exclusively binary mixtures had been investigated. Ternary mixtures are prototypes for the important class of truly multicomponent systems.

2005 First measurements in true ternary mixture.
A. Leahy-Dios, M.M. Bou-Ali, J. K. Platten, A.Firoozabadi, JCP, 122, 234502

The **long-term vision** is to understand thermal diffusion in multicomponent systems. Ternary systems are merely the first step in this direction. But even this step is rather complicated and ternaries are already very different from binaries.

Space research started with multi-objective project IVIDIL
Earth benefits

Petroleum exploration: Data from these space studies may help the oil industry generate formulas to predict correct measurements for the liquid to gas ratio in potential wells.

Phase separation in polymer blends has potential application for nanotechnology in diverse fields, ranging from bioactive patterns to polymer electronics.

DNA molecules drift along temperature gradients

Duhr & Braun, PNAS, 2006

Experiments with temperature dependent surface tension force: Marangoni convection

JEREMI – Japanese European Experiments on Marangoni instability, KIBO (JEM) module of the ISS

What is Marangoni convection?

\[ \sigma \text{ and } \frac{d\sigma}{dT} \]

Credit to Jaxa
Experiments with temperature dependent surface tension force: Marangoni convection

JEREMI – Japanese European Experiments on Marangoni instability, KIBO (JEM) module of the ISS
In the early days of spaceflights, it was believed that crystals of exceptional quality could be grown from the melt in the microgravity environment due to the absence of the undesired buoyant convection.

Oscillatory Marangoni convection can create striation on the crystal.
Earth benefits

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Oscillatory Marangoni convection can create striation on the crystal
Vibration induced flows

Vibration may act as artificial gravity in fluids with non-uniform density, i.e. create convective flows.

Thus they are important for:

✿ Mixing
✿ Dissolution
✿ Interfacial mass transfer
✿ Control of liquids in space

Accent on miscible liquids
The observation principle is shadowgraphy. It allows to see only the derivative of the refractive index with density/concentration.

The region with large variation of refractive index, i.e. large variation of density is visible as black line.

\[ g_{os} = 6.5g_0, \quad \text{Vel} = A\omega = 0.844\text{m/s} \]
Miscible liquids in Earth gravity condition

Frozen wave instability
Parabolic flight environment
Miscible liquids in microgravity

$A = 4 \text{ mm}, f = 20 \text{ Hz}$
Miscible liquids in microgravity

$A = 4 \text{ mm, } f = 20 \text{ Hz}$
http://www.esa.int/spaceinimages/Images/2015/06/A_new_mix

Science meets art

Image of the week of the European Space Agency
Science meets art

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Image of the week of the European Space Agency

Not to be conducted on the ISS due to lack of funding
What is the future of microgravity research on the ISS?

To enhance international collaboration
Mars colonization

Ilon Musk (Space-X) plan: to create sustaining colony on the Red Planet within the next 50 to 100 years.

Any mission to Mars will require highly reliable habitation systems to keep the crew healthy and productive in the deep-space environment during missions that last up to 1,100 days (NASA)
Research on liquid phase behaviours in weightlessness conditions on board of:


Foton 12: experiments on Bifurcation Anomalies in Marangoni Benard Instabilities (1999).

Microgravity platforms

- Drop Towers up to 9s
- Parabolic flights ~22s
- Sounding Rockets~6-12 min
- Space Station

ISS is unique Platform for Science:
- suitable for long-term studies;
- possible crew assistance;
Soret coefficients

A difficult and unfortunate subject?

EURECA 1 mission (1992)
• Computer clock of SGF stopped the experiment periodically
• Pressure compensation membranes
• Over tested valves
CIRUS GAS-Can, C-CORE (1998) : CSA computer failure
FOTON 12 (1999) : leaking at high pressure
FOTON M1 (2002): see film
FOTON M2 (2005) : partly successful
IVIDIL (2009-2010) : Soret + vibrations . PERFECT
DC MIX 1 : Delayed due to Facility problems
DC MIX 2 : to fly soon for ternary mixtures
Team work on the ground and in microgravity

Belgian PI

THN-IBB-nC12 (0.80-0.10-0.10)