

CZECH CONTRIBUTION TO LOFT

RENÉ HUDEC^{a,b,*}, VOJTĚCH PETRÁČEK^c, DALIMIL ŠNITA^d^a *Astronomical Institute, Academy of Sciences of the Czech Republic, CZ-25165 Ondřejov, Czech Republic*^b *Czech Technical University in Prague, Faculty of Electrical Engineering, Technická 2, CZ-16627 Prague, Czech Republic*^c *Czech Technical University in Prague, Faculty of Nuclear Engineering, Břehová 78/7, CZ-11000 Prague, Czech Republic*^d *Institute of Chemical Technology, Technická 5, CZ-16628 Prague, Czech Republic** corresponding author: rhudec@asu.cas.cz

ABSTRACT. We describe the current status of the Czech contribution to the ESA LOFT space mission, with emphasis on technical aspects. Expertise available in the Czech Republic will play a positive role in the LOFT project and related developments.

KEYWORDS: X-rays, X-ray astronomy, X-ray satellites, LOFT.

1. INTRODUCTION: THE LOFT MISSION

LOFT, the Large Observatory For X-ray Timing, is a newly proposed space mission intended to provide answers to fundamental questions about the motion of matter orbiting close to the event horizon of a black hole, and the state of matter in neutron stars (Feroci et al., 2011). LOFT was recently selected by ESA as one of the four space mission concepts of the Cosmic Vision programme that will compete for a launch opportunity at the beginning of the 2020s. The ESA LFT M class mission candidate is specifically designed to exploit the diagnostics of very rapid X-ray flux and spectral variability that directly probe the motion of matter down to distances very close to black holes and neutron stars, and also the physical state of ultradense matter (Feroci et al., 2011).

LOFT will investigate variability from submillisecond QPOs to transient outbursts lasting years. The LOFT LAD has an effective area ~ 20 times larger than its largest predecessor (the Proportional Counter Array on board RossiXTE) and much improved energy resolution.

The LOFT WFM will discover and localise X-ray transients and impulsive events, and will monitor spectral state changes, triggering follow-up observations and providing important science in its own right. The basic technologies for LOFT include:

- (1.) Large Area Silicon Drift Detectors;
- (2.) Capillary plate X-ray collimators (Feroci et al., 2011).

The Large Area Detector (LAD) for LOFT has a fully modular and redundant approach: there are 16 independent detectors per Module, 21 independent Modules per Detector Panel, and 6 independent Detector Panels per LAD.

The Wide Field Monitor for LOFT is based on the same type of Si detectors as the Large Area detector, but it has finer pitch ($300\ \mu\text{m}$): $< 60\ \mu\text{m}$ 1D position resolution coarse ($\sim 3\ \text{mm}$) 2D resolution. It has 8 cameras, 4 units, and rectangular FOV $180^\circ \times 90^\circ$ (at zero resp., each camera/unit $90^\circ \times 90^\circ$)

The Capillary-plate Collimator is an important part of the LOFT instrumentation. Lead-glass microcapillary plates are commercially available and can be customized. The LOFT baseline is as follows: FOV to $\sim 43'$ FWHM (2 mm thickness, $25\ \mu\text{m}$ hole diameter, $28\ \mu\text{m}$ pitch, Open Area Ratio 80%). The heritage is recently based on Microchannel Plates (MCP, e.g. Chandra satellite). For more details on LOFT and its onboard experiments, see Feroci et al., 2011.

2. CZECH PARTICIPATION IN LOFT

The Czech Republic has been a full ESA member state for almost 4 years. The LOFT mission is the 2nd ESA high-energy satellite with official Czech participation (after INTEGRAL). The following consortium is expected to handle all aspects of the Czech contribution to LOFT.

2.1. THE CZECH LOFT TEAM/CONSORTIUM

The following Czech institutes are involved in the ESA LOFT mission and related studies:

- (1.) Czech Technical University in Prague (CTU);
- (2.) Astronomical Institute Academy of Sciences of the Czech Republic, Ondřejov (AI);
- (3.) Institute of Chemical Technology (IChT);
- (4.) Silesian University at Opava (SU).

The Czech LOFT Consortium has the following members: René Hudec CTU & AI, Vojtěch Petráček CTU, Miroslav Finger MFF UK, Václav Vrba FZU AV

ČR, Dalimil Šnita IChT, Vladimír Karas AI, Vojtěch Šimon AI, and Zdeněk Stuchlík SU.

The wider Czech LOFT consortium has 3 sections: scientific, technical, and industrial, and the members are as follows.

Scientific group: V. Karas, Z. Stuchlík, M. Bursa, M. Dovciak, J. Horak, V. Šimon. R. Hudec and G. Torok.

Technical group: V. Petráček, D. Šnita, L. Pína, R. Hudec, M. Finger, V. Vrba and O. Gedeon.

Industrial group: V. Maršíková, A. Inneman, M. Holl and P. Bareš.

2.2. GOALS OF CZECH PARTICIPATION

The following points indicate the anticipated goals of Czech participation in the LOFT mission.

- Contribute to *Science* through the LOFT mission – X-ray and BH (black hole) astrophysics
- Participate in the study, design and development of a major onboard experiment (large area detector), and contribute to *Silicon drift detector* design, development and tests.
- Possibly participate in studying and designing alternative *glass capillary plate* technology for the large area detector
- Complete the study and design of an additional small *Czech Lobster Eye X-ray All Sky Monitor*
- Ensure *participation by Czech industry* in various onboard experiments and satellite parts and systems, hardware and software, if the mission is selected.

In this paper we focus on technical participation in the LOFT project. Scientific aspects will be addressed in a separate forthcoming paper.

2.3. EXPERTISE AVAILABLE (FOR LOFT)

Expertise in the following fields is available in the participating Czech institutions:

- Si drift detectors (Czech Technical University);
- Polycapillary glass plates (Institute of Chemical Technology);
- Wide-Field Lobster Eye X-ray Monitors;
- X-ray and BH astronomy and astrophysics (Astronomical Institute, Silesian University at Opava, Charles University);
- Space industry — hardware and software (Czech Space Alliance, small companies and larger companies);
- Data analyses (ISDC participation).

2.4. POLYCAPILLARY GLASS PLATES

Polycapillary glass plates form a significant part of the onboard instrumentation. Below we offer a brief description of a possible option based on experience available in Czech institutions.

- A possible alternative solution for MCP: a recent version of our photolithographic method had glass 0.2–1.6 mm in thickness 100×100 mm, holes as small as 50 microns.
- Developed by D. Šnita, Institute of Chemical Technology in Prague.
- Will need to be further developed if it is to be used in the LOFT project.

2.5. SILICON DRIFT DETECTORS

The silicon drift detectors (SDD) are key instrumentation for LOFT. The following expertise is available in Czech institutions.

- Extended Czech participation in detectors for the ALICE ground-based experiment.
- Expertise available in design, development, manufacture and tests of SDD.
- CTU (Czech Technical University) in Prague, Institute of Physics, and ON Semiconductor Czech Republic are the main Czech institutions involved.
- SDD was invented by Czech scientist Pavel Rehak.

3. SDD IN PRAGUE – THE TEAM’S QUALIFICATIONS AND RESOURCES

In this section, we briefly introduce the qualifications and resources of the Czech SDD teams.

3.1. TEAM COMPOSITION (EXPERIENCE WITH SDD):

The expert team is concentrated in the Center for Physics of Ultra-relativistic Heavy Ion Collisions, consisting of teams from CTU in Prague and from the Institute of Nuclear Physics of the Academy of Sciences of the Czech Republic. The following institutes are the main partners.

Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague. This institute has experience in detector design, development, prototype production, detector testing, experimental operation of SDD, radiation damage tests, detector defect simulation, calibration, data analysis, development of the control system for SDD. WA98, and NA45-2 CERES and ALICE experiments.

Nuclear Physics Institute. This institute has expertise in detector assembly, operation, testing, data analysis, NA45-2 CERES, SDD calibration and analysis, and SDD laboratory tests.

3.2. LABORATORY INFRASTRUCTURE CURRENTLY AVAILABLE FOR THE SDD PROGRAM

The following laboratory infrastructure is available to support SDD-related studies and developments:

FNSPE CTU Prague — clean room facility, probestation, AC-DC test equipment (LRC), laser charge injection, bonding station (small, manual), dark box;

NPI ASCR — clean room, probestation, test equipment, bonding station, irradiation facility (n-source, cyclotron);

CERN — beam test (if needed).

3.3. PRODUCTION EXPERTISE

The collaboration teams also have the following production expertise:

- prototype production of SDD for the ALICE experiment – ICM Prague;
- Post-prototyping contacts in the ON Semiconductor: Roznov, Czech Republic (together with our team, the company tested double-sided technology and later successfully produced many of the pixel detectors for the ATLAS detector at LHC);
- selection and detector tests – participation in detector construction (Trieste and Torino);
- design and production of the low voltage power supply system for ALICE SDD.

4. THE LE (LOBSTER-EYE) ALL SKY MONITOR

In addition, we plan to further exploit the modular concept of the LE all-sky X-ray monitor (Hudec, 2011, Tichy et al., 2011), as a possible low-energy addition to the recently considered LOFT onboard instrumentation. The modular LE concept offers easy modification for EXIST, HXMT or other satellites. One module can be as small as $5 \times 5 \times 30$ cm, ~ 2 kg, and hence can be considered as a supplementary onboard instrument for LOFT. The basic estimated parameters for an array of 30 modules are given below:

- daily limiting flux 10^{-12} erg/s/cm²;
- one module 2×195 plates $78 \times 11.5 \times 0.1$ mm, 0.3 mm spacing;
- detector pixel size 150 microns;

- total front area 1825 cm²;
- energy range 0.1–10 keV;
- FOV 180×6 degrees (30 modules 6×6 degrees);
- angular resolution 3–4 arcmin;
- total mass < 200 kg (for 30 modules).

5. CONCLUSIONS

After ESA Athena was not selected for the ESA L mission, LOFT is the only remaining X-ray astronomy mission under consideration by ESA for the future. For the Czech teams, LOFT is (after INTEGRAL) the 2nd ESA high-energy astrophysical mission with official Czech participation.

This paper has provided a brief review of possible Czech participation in the LOFT mission and the contribution that Czech institutes are able to make. The exact extent of our participation will depend on the available funding. Despite extensive efforts, no funding was available at the time when this paper was written. However, recent changes in the organization of Czech space activities and the plan to establish a Czech National Space Agency give good hope that the situation will improve soon, enabling more a effective Czech contribution to the LOFT mission.

ACKNOWLEDGEMENTS

We acknowledge the support provided by the Grant Agency of the Czech Republic within the framework of grants 102/09/0997 and 13-33324S “Lobster Eye X-Ray Monitor”.

REFERENCES

- [1] M. Feroci, L. Stella, M. van der Klis. The Large Observatory for X-ray Timing (LOFT), *Experimental Astronomy*, 2011.
- [2] R. Hudec. New Types of Astronomical X-Ray Optics. Vulcano Workshop 2010 Frontier Objects in Astrophysics and Particle Physics, Conference Proceedings, Italian Physical Society, Vol. 103, pp. 643–648, 2011.
- [3] V. Tichý, M. Barbera, A. Collura, et al. Lobster eye optics for nano-satellite x-ray monitor, *EUV and X-Ray Optics: Synergy between Laboratory and Space II*. Edited by Hudec, René; Pina, Ladislav. Proceedings of the SPIE, Volume 8076, pp. 80760C–80760C-13 (2011)