Space activities in High Energy Astrophysics

René Hudec, High Energy Astrophysics Group,
ASÚ AV ČR Ondřejov & CTU FEE Prague

Lanna Nov 12, 2021

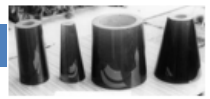
CTU – ASU Cooperation in Space Projects

- Cooperation started in 1970 – INTERKOSMOS X-ray telescopes
- Where CTU covers the technical/instrumental part of the projects and ASU the scientific/astrophysical one, and, in addition, provides ground based robotic telescopes to support the satellite projects/observations

HISTORY OF GRAZING INCIDENCE X-RAY OPTICS IN THE CZECH REPUBLIC

Hudec, R "History of grazing incidence x-ray optics in the Czech Republic," Proc. SPIE 7360, EUV and X-Ray Optics: Synergy between Laboratory and Space, 73600D (30 April 2009); doi: 10.1117/12.820356

All of the X-ray imaging telescopes onboard Soviet spacecrafts were equipped with the Czech X-ray optics



1969 First considerations started

1970 First X-ray mirror (Wolter 1; 50 mm)

Development before 1987 completely independent without any contact to other groups and without access to relevant literature and/or meetings and workshops

1976 Wolter 1; 115 mm AUOS-S-IK

1979 First mirrors flown in Space (2xtwo Wolter 50 mm) VERTIKAL8 and 9

1981 Salyut 7 orbital station RT-4M (Wolter 240 mm nested)

1985 Applications for plasma physics, EH 17 mm, PP 20 mm

1988 FOBOS 1 Mars probe, TEREK X-ray Telescope Wolter 80 mm

1989 KORONAS I, Wolter 80 mm

1990 First micromirror (apertura less than 1 mm)

1993 Collaboration with SAO, USA, WF X-ray optics started

1996 First Lobster Eye (Schmidt)

1999 Lobster Eye (Angel)

2000 Soller Slit

2001 Multifoil optic

2002 Micromirror with multilayers

Glass foil mirrors

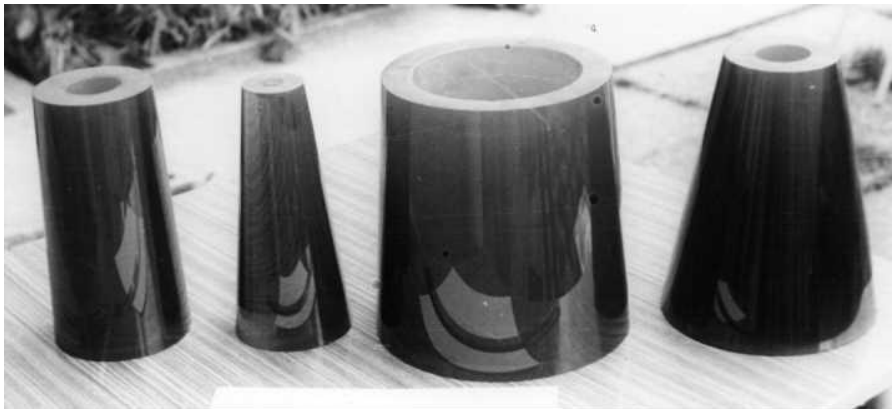
2006 Si wafer mirrors

2007 Micromirror – test at HASYLAB

2010-20: LE optics, KB optics, novel technologies, miniature telescopes, active optics

Total number of X-ray mirrors produced: more than 50
Total number of mirrors flown in space: 8 (10)
Total spacecrafts with Czech X-ray optics: 4 (5)
Total number of space experiments with Czech X-ray optics onboard: 8

X-ray Telescopes long CZ history 1970 -



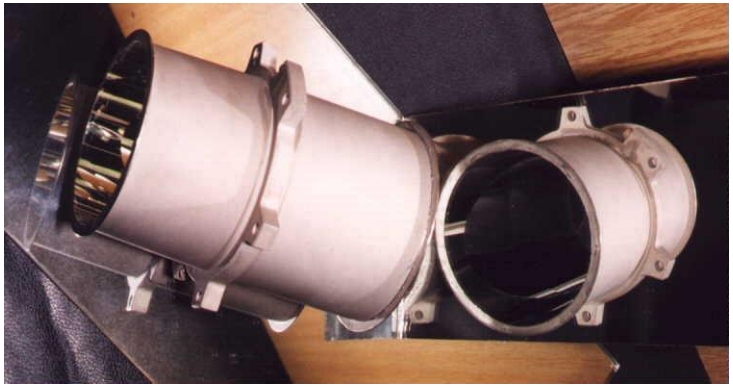
The four mandrel used for the manufacture of X-ray mirror nested array for the RT-4M soft X-ray telescope (Glass ceramics Sital). Flown onboard the space station Salyut 7 in 1981.

TEREK

Phobos 1

1988

Two identical mirrors (large hyperbolas) of the RT-4M mirror array (Ni surfaces), 1981.



Replicated Wolter - 1 X-ray mirrors of the KORONAS satellite (aperture 80 mm), 1989

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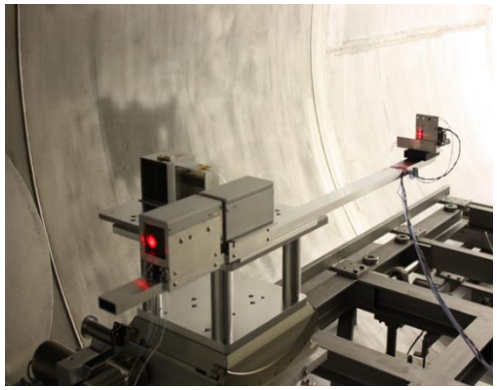
Space Projects

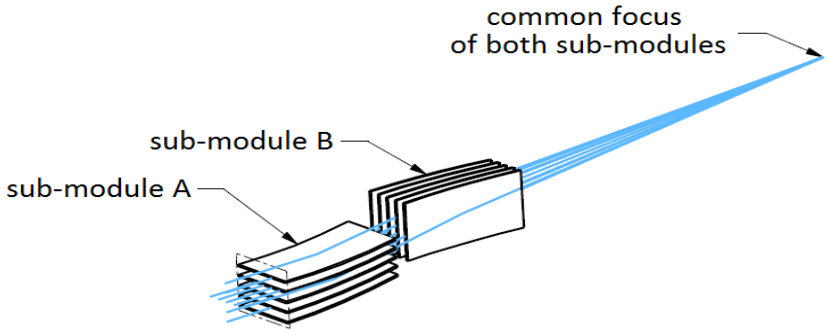
- ESA INTEGRAL & OMC camera
- ESA SMILE, THESEUS, participation in main cons level
- ESA ATHENA
- EU H2020 AHEAD Integrated Activities in High Energy Astrophysics
- Cubesat related activities, payloads, optics, telescopes, detectors
- Rocket experiments
- Robotic telescopes as ground based support
- ESA Gaia: optical follow up for Gaia alerts

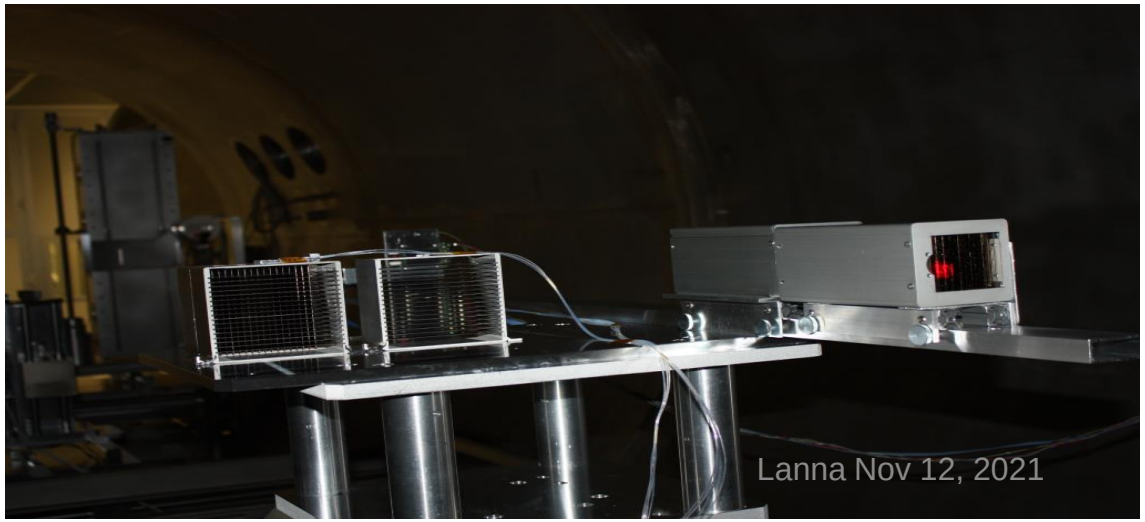
Educational space activities

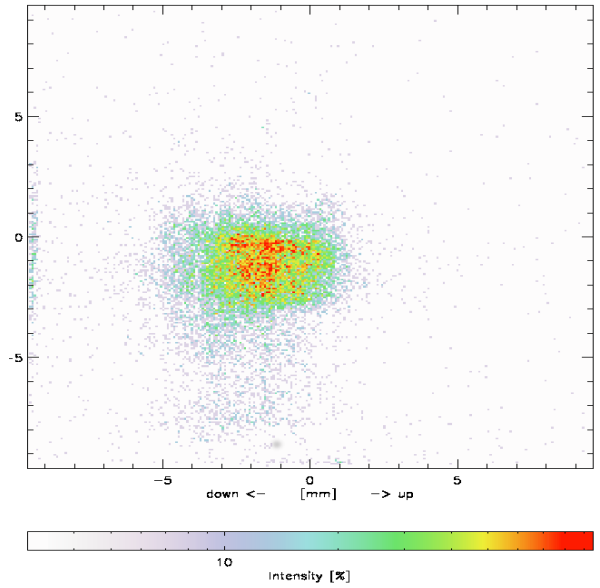
- Teaching Space engineering for Master students
- Teaching Space Science and Engineeering PhD students
- Supervising space PhD students
- Organization of summer schools and workshops

ESA ATHENA: alternative optics in KB arrangements. Kirkpatrick Baez modules in PANTER X-ray test facility

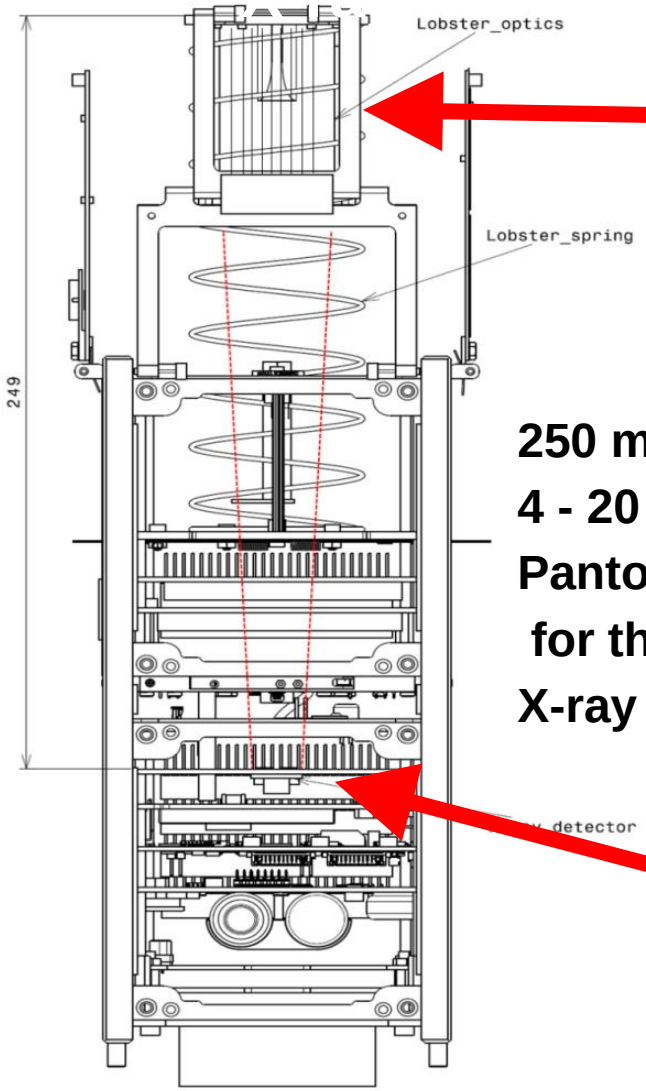


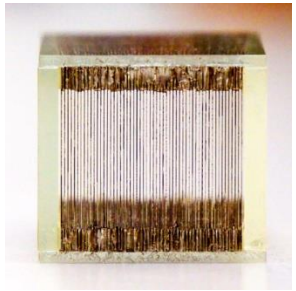


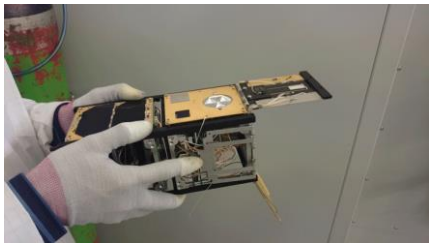




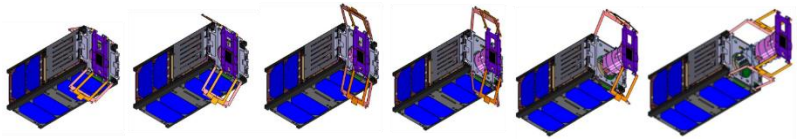
Lobster eye optics

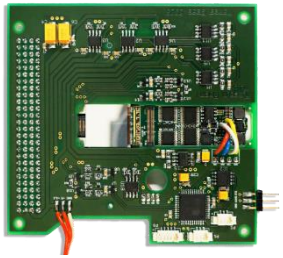






250 mm focal length
4 - 20 keV energy range
Pantograph based mechanism for the optics deployment
X-ray beam goes through 5 other electronic boards



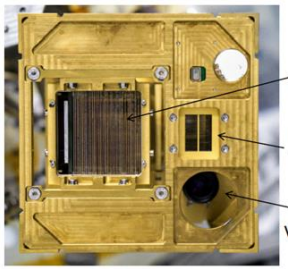


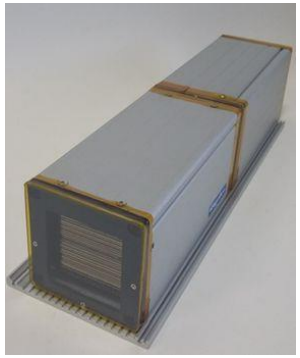
Timepix board

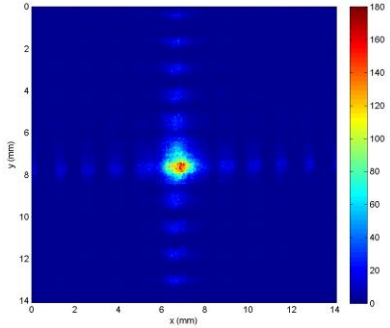
Urban, M., O. Nentvich, V. Stehlikova, T. Baca, V. Daniel, and R. Hudec: VZLUSAT-1: Nanosatellite with miniature lobster eye X-ray telescope and qualification of the radiation shielding composite for space application, Acta Astronautica, Volume 140, id.96 (2017)

LE optical system for NASA rocket experiment (REX I)

Rocket launch in 2018







Verification of wide-field monitoring in energy range 3-40 keV using MFO

Verification of electronics and Timepix detector with no cooling

Imaging separately by 1D and 2D LE optical system

Collaboration with the Pennsylvania State University, team of Prof. Randall L. McEntaffer

Launch 03.04.2018 (Kwajalein Atoll)

Dániel, V., R. Hudec, T. Baca, L. Pina, A. Inneman, V. Marsikova, M. Urban, O. Nentvich, V. Stehlikova, and J. Tutt: REX LE X-ray telescope experiment overview, EUV and X-ray Optics: Synergy between Laboratory and Space VI, Volume 11032, id.1103206 (2019)

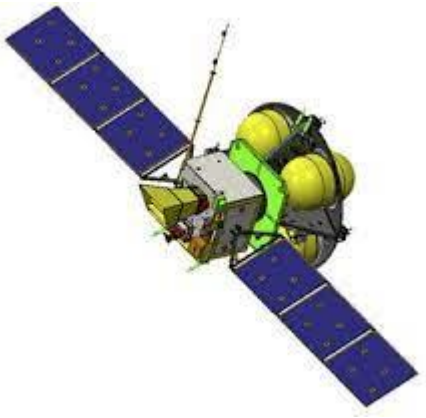
Stehlikova, V., M. Urban, O. Nentvich, A. Inneman, T. Döhring, and A.-C. Probst: Study of lobster eye optics with iridium coated x-ray mirrors for a rocket experiment, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Volume 10235, id.1023505 (2017)

Involvement of my PhD students with relevant publications

SMILE and THESEUS

- **Both ESA missions with Czech participation on main consortium level and payload contribution**
- **Both mission with SXI soft X ray telescope with Lobster Eye type wide field optics**

SMILE: ESA-CAS (China)



Solar wind Magnetosphere
Ionosphere Link Explorer

- **Small spacecraft (<300 kg) and payload (<60 kg)**
- **SMILE formally selected by ESA SPC in early November 2015**

Solar Wind Charge eXchange (SWCX) X-ray imaging of the dayside magnetosheath and the cusp

Investigate the dynamic response of the Earth's magnetosphere to the solar wind impact in a unique and global manner

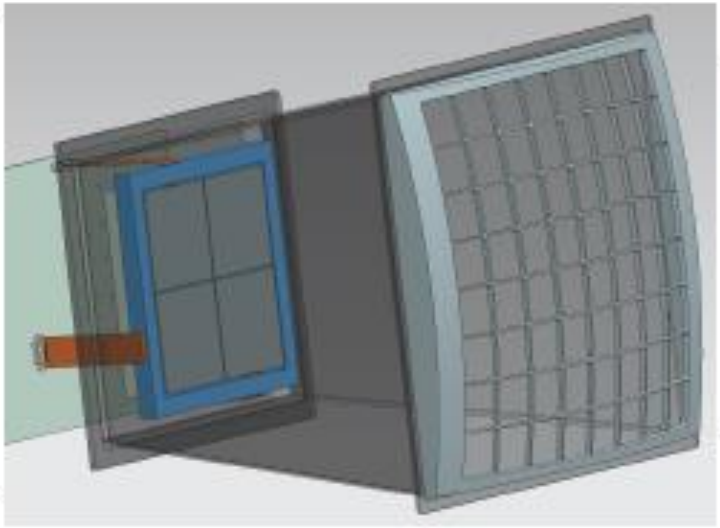
SMILE Soft X-ray Imager (SXI)

CCD Detector Plane

Photon counting

High QE in soft X-rays
~80% at 250 eV

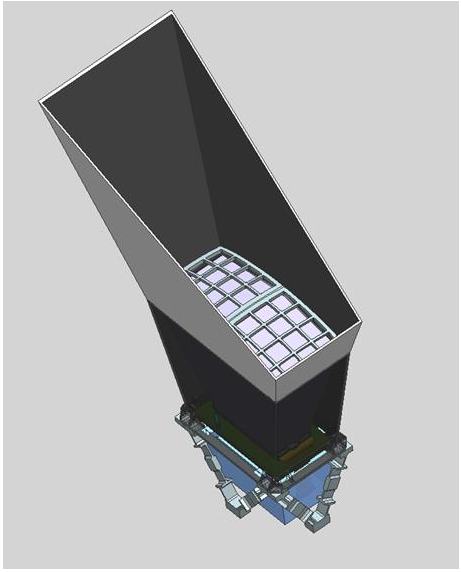
Medium energy resolution
~50 eV FWHM at 500 eV

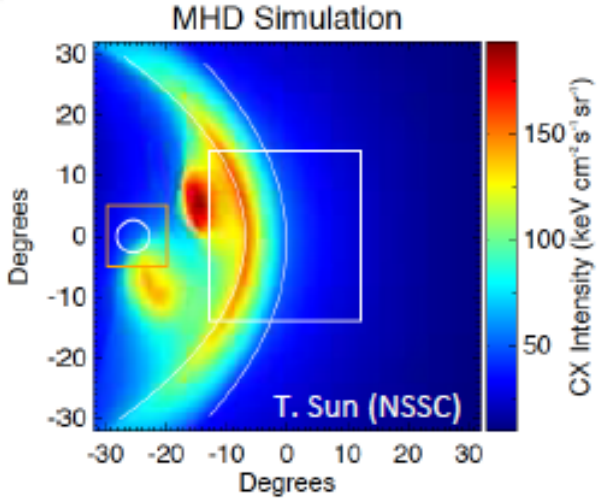


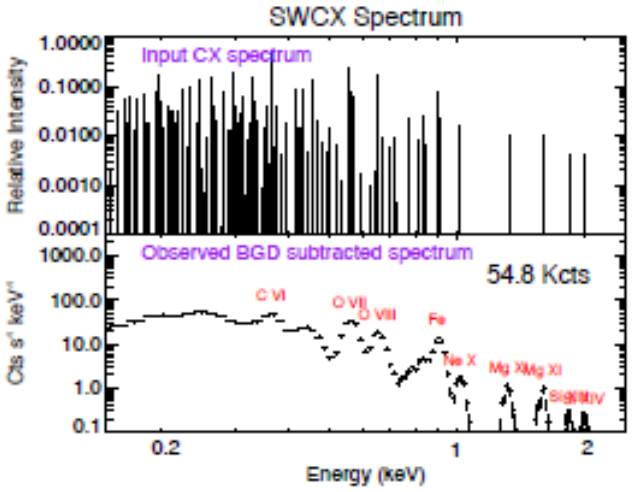
Lobster-eye Micropore Optic

Ultra-wide field of view
~25°x25°

Low Mass
~ 1kg optic array







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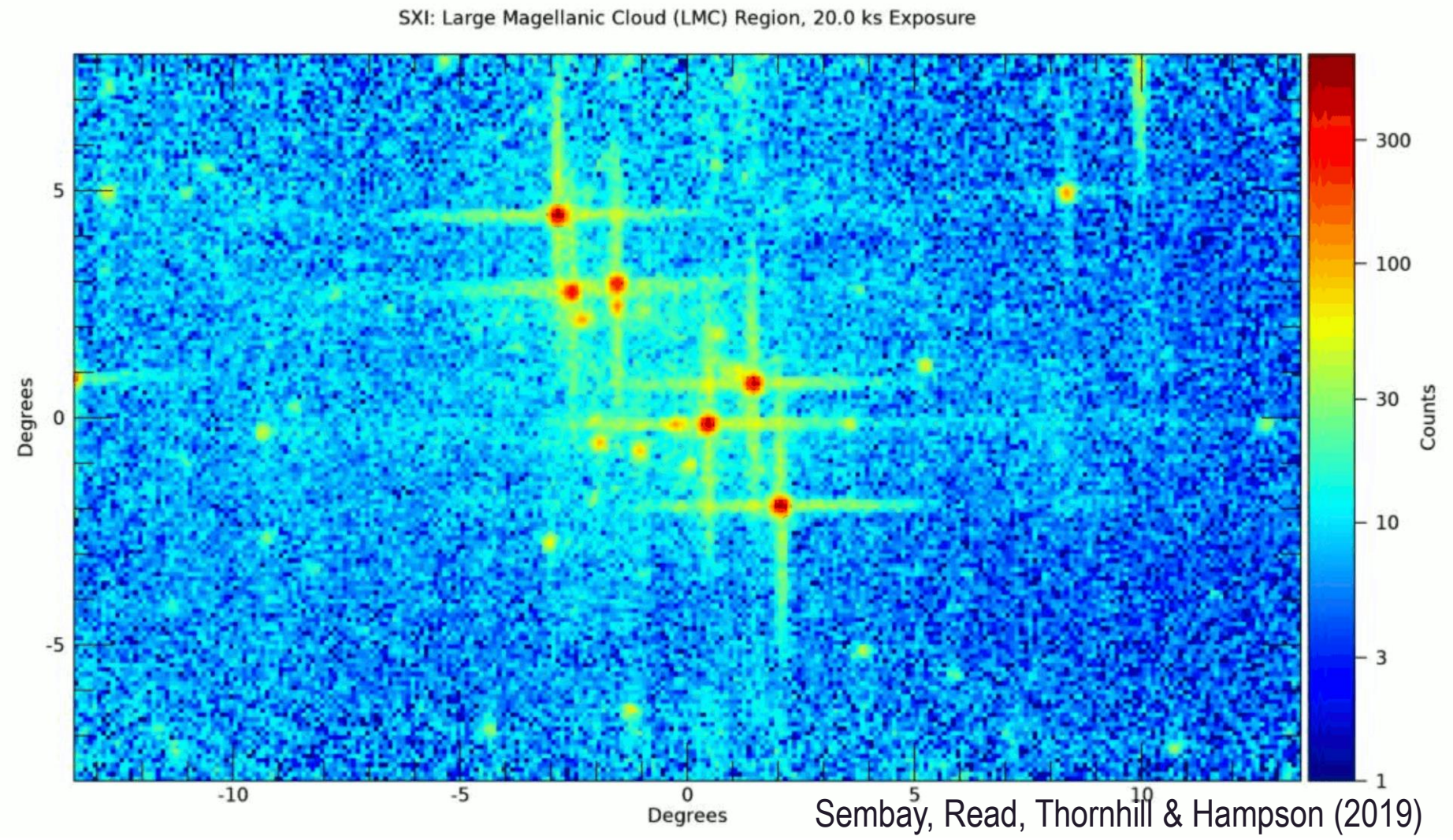
S. Sembay, Leicester Univ., UK

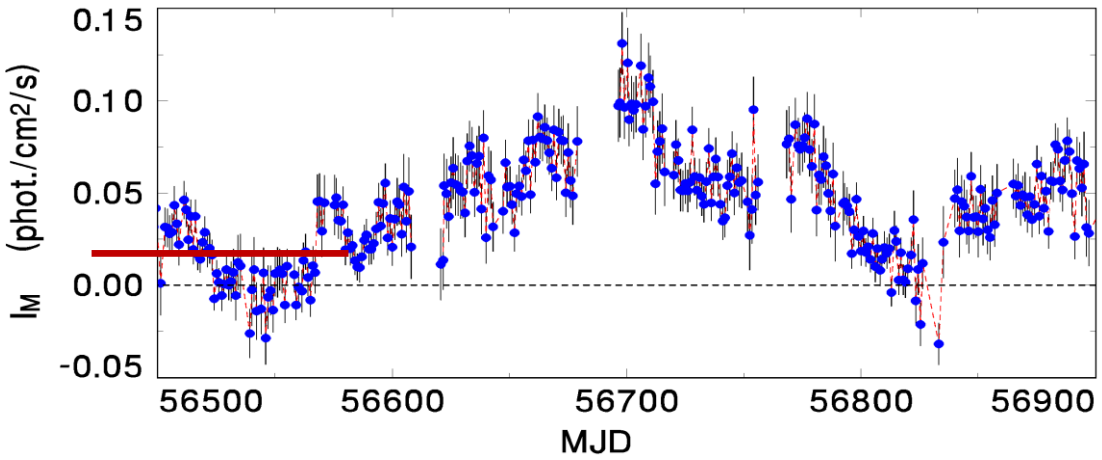
Detection of cosmic sources with SXI/SMILE



Sembay, Read, Thornhill & Hampson (2019)

- LMC; exposure time 20 ks (~4,3 hours)
- Point sources will be well defined

LMC X-3 in the field of view of SXI/*SMILE*



Detail of X-ray light curve (2-3 keV)
1-day means, integration time: ~30 min per day

ISS / MAXI data
(2 – 3 keV)
Simulation of observing with SXI/SMILE

Perspective of analysis of cycles of complex long-term activity

Expected limit for 1000 s of int. time of SXI/*SMILE*

Secondary Science: X-ray binaries for SXI/*SMILE*

- **High-mass X-ray binary in the Magellanic cloud**
- **Black hole + lobe-filling B-type mass-donating star**
- **Orbital period of 1.7 day, but X-ray variations occur on super-orbital time scale (often weeks)**

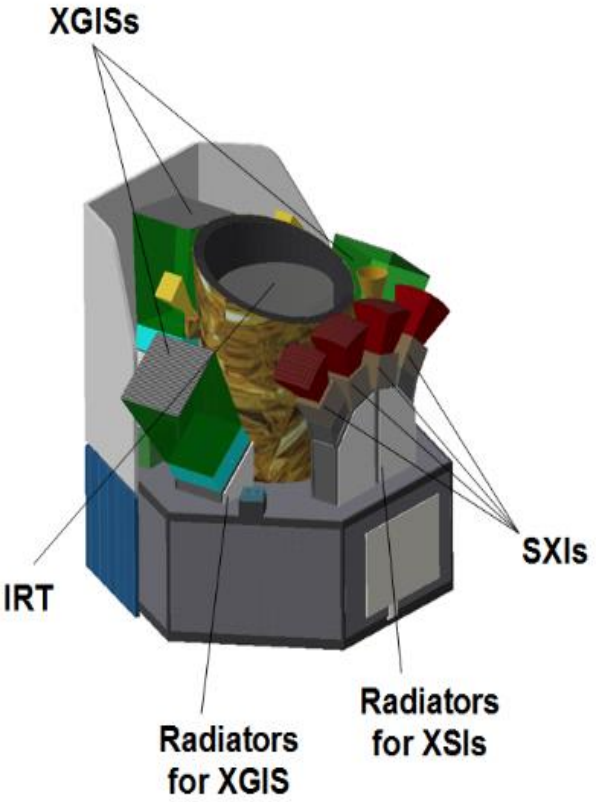
- **SMC X-1:** superorbital X-ray modulation, persistent accretion disk (neutron star+B0 supergiant)
- LMC X-2: low-mass X-ray binary, neutron star accretor, Z-source
- LMC X-3: high-mass X-ray binary, black hole
- SMC X-2: transient X-ray pulsar, neutron star+Be binary
- SMC X-3: transient X-ray source, neutron star+Be
- CAL 83: thermonuclear accretion on the white dwarf
- CAL 87: thermonuclear accretion on the white dwarf

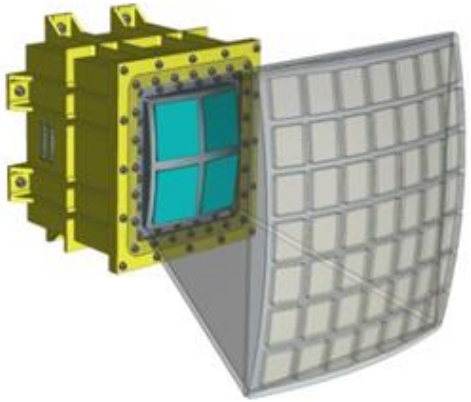
ESA THESEUS mission: ESA M5 call

Transient High Energy Sources and Early Universe Surveyor

- **Soft X-ray Imager (SXI):** a set of four sensitive lobster-eye telescopes observing in **0.3 - 5 keV band, total FOV of ~1sr with source location accuracy 0.5-1';**
- **X-Gamma rays Imaging Spectrometer**
- **InfraRed Telescope (IRT)**:

performing an unprecedented deep survey of the soft X-ray transient Universe

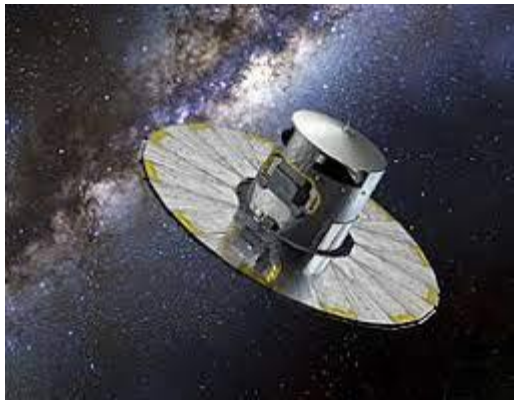




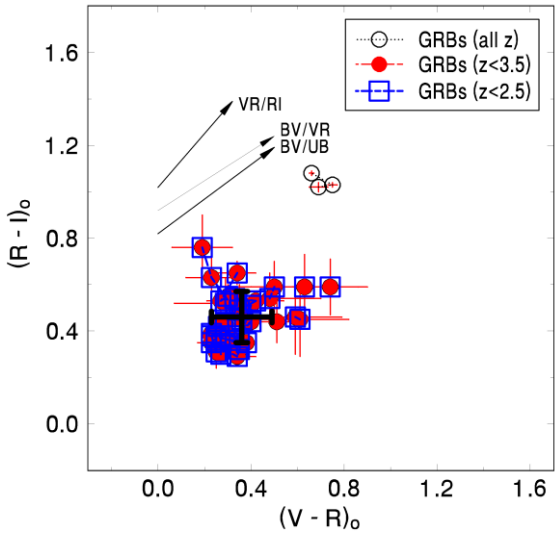
In final competition not selected, but consortium will try to submit again

LEO (< 5°, ~600 km)
Rapid slewing bus
Prompt downlink

ESA Gaia



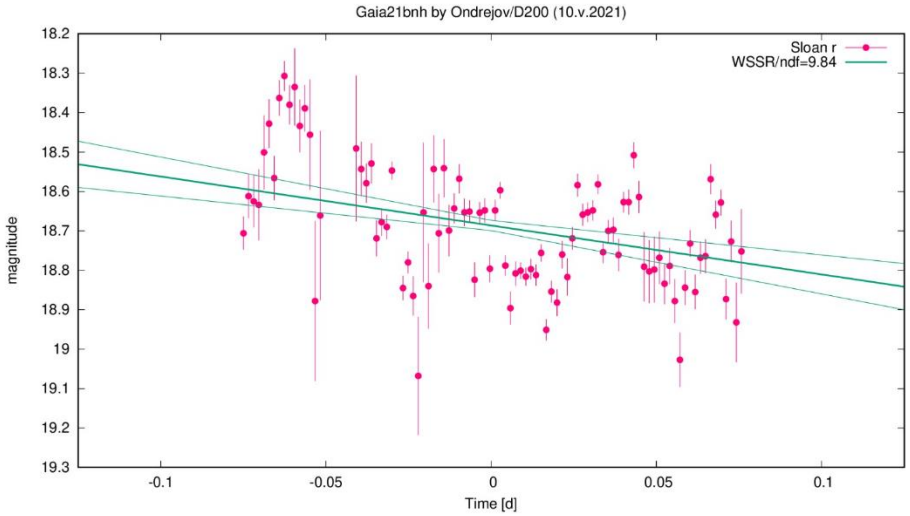
- **Participation in Gaia Photometric Science Alerts system by providing follow-up by our robotic telescopes**
- **With emphasis on microlensing events, blazars and cataclysmic variables, mostly new and with very large amplitudes**
- **Use of Gaia data with emphasis on RP,BP for study of HE sources:**
- **Color-color analyses and LDS**

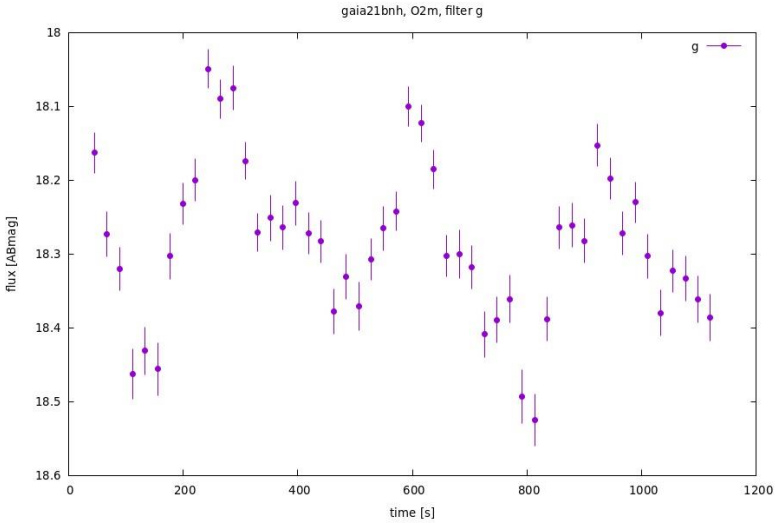


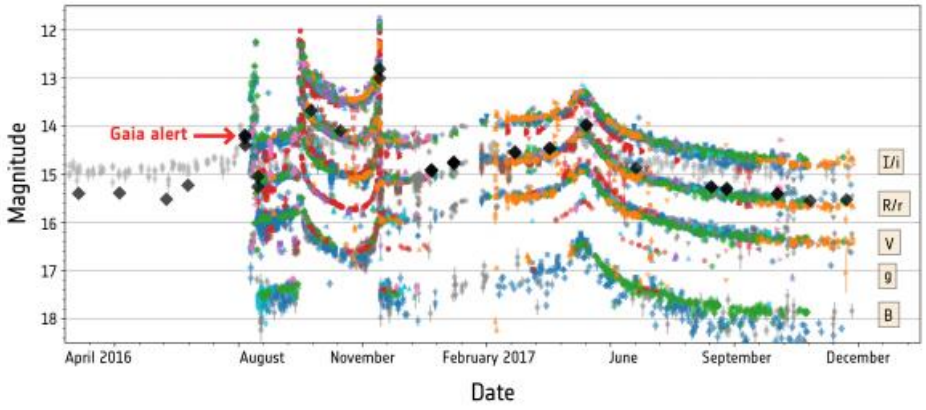
Recently 3 RTs: BART, D50, SBT

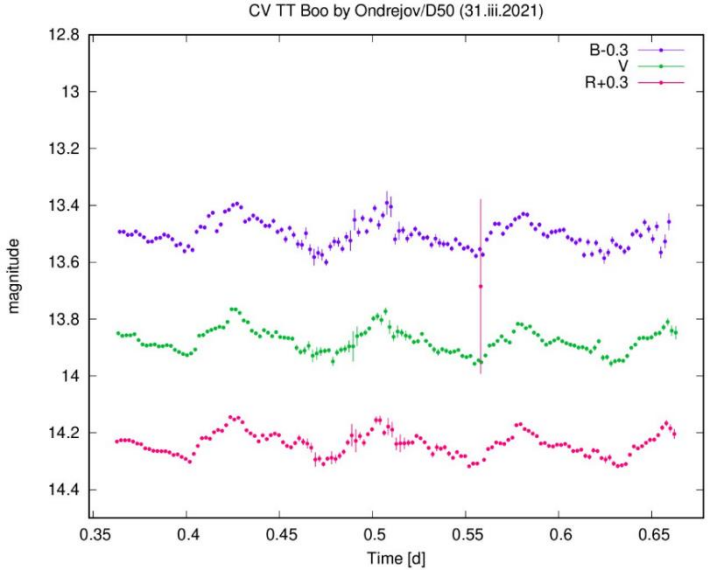
Ground-based support for satellite projects, observing campaigns etc.

Examples of Gaia photometric alerts observed by our RTs









Organization of international conferences

- **IBWS INTEGRAL/BART workshop from 2002, annual**
- **AXRO International Workshop on Astronomical X-ray Optics from 2008, annual**
- **SPIE Conference EUV and X Ray Optics Synergy between Laboratory and Space bi-annual since 2009**

Space activities at FEL CVUT (all)

- https://fel.cvut.cz/en/research/space-activities.html

The End

Thanks for your attention