Kosmické projekty a aktivity v oblasti astrofyziky vysokých energií

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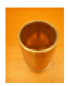
ASÚ AV ČR Ondřejov

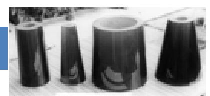
Lanna Nov 12, 2021

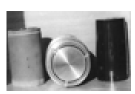
HISTORY OF GRAZING INCIDENCE X-RAY OPTICS IN THE CZECH REPUBLIC

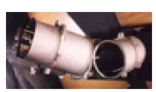
Hudec, R "History of grazing incidence x-ray optics in the Czech Republic," Proc. SPIE 7360, EUV and X-Ray Optics: Synergy between Laboratory and Space, 73600D (30 April 2009); doi: 10.1117/12.820356

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

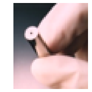
1979 — First mirrors flown in Space (2xtwo Wolter 50 mm) VERTIKAL8 and 9

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

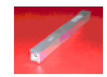
1989 — KORONAS I, Wolter 80 mm



1990 — First micromirror (apertura less than 1 mm)

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

1996 — First Lobster Eye (Schmidt)

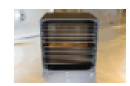


1999 — Lobster Eye (Angel)

2000 — Soller Slit

2001 — Multifoil optic

2002 — Micromirror with multilayers



Glass foil mirrors

2006 — Si wafer mirrors

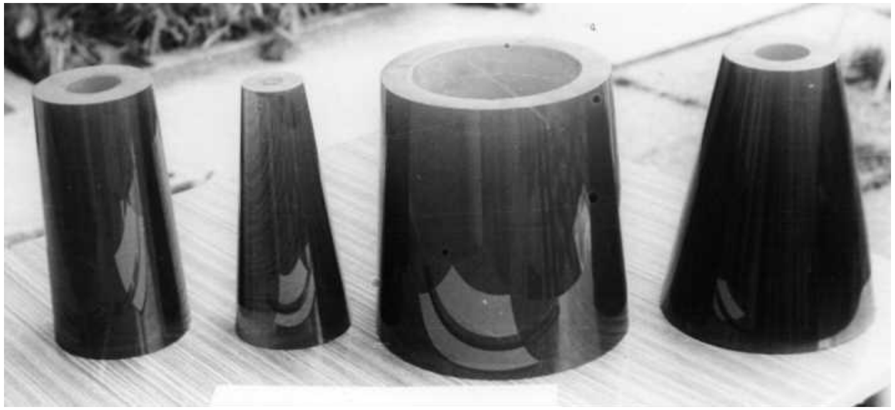
2007 — Micromirror – test at HASYLAB

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 -

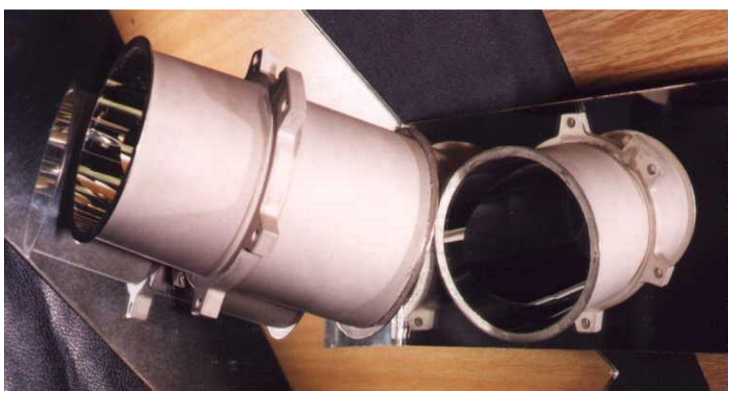


The four mandrel used for the manufacture of X-ray mirror nested array for the RT-4M soft X-ray telescope (Glass ceramics Sital). Flown onboard the space station Salyut 7 in 1981.

TEREK

Phobos 1

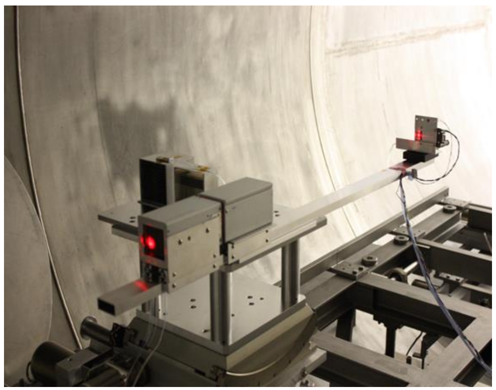
1988

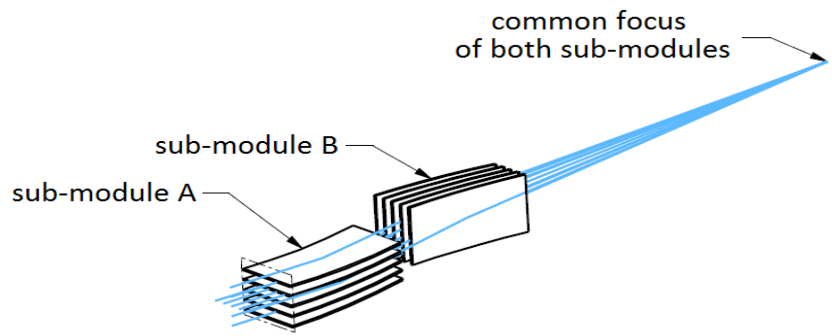


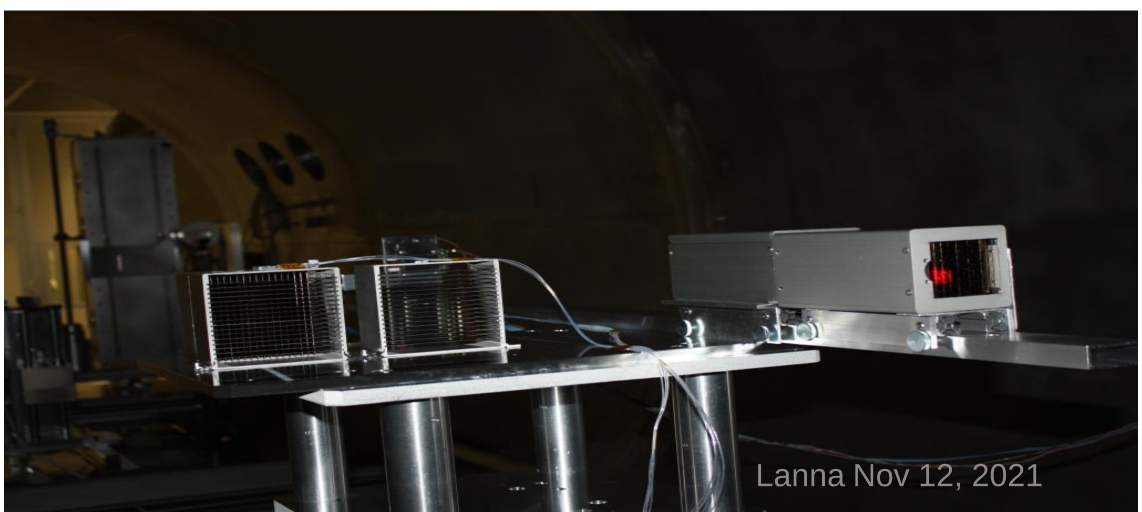
Replicated Wolter - 1 X-ray mirrors of the KORONAS satellite (aperture 80 mm), 1989

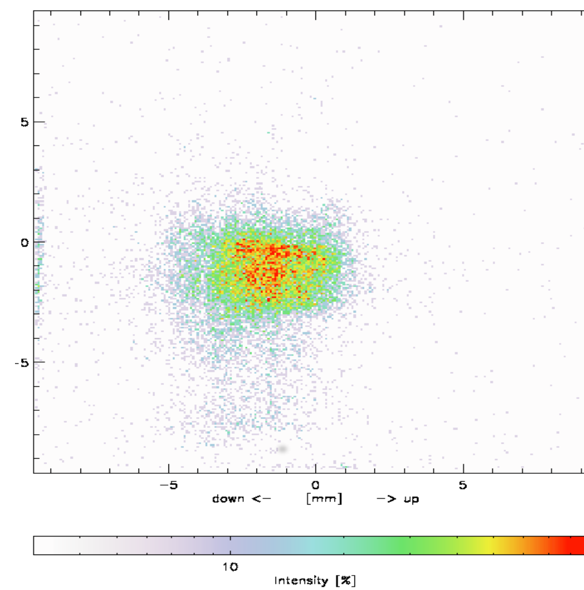
Two identical mirrors (large hyperbolas) of the RT-4M mirror array (Ni surfaces), 1981.

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









The ESA INTEGRAL Mission

Gamma-ray observatory with concurrent X-ray and optical monitoring.

INTEGRAL is the ESA Science Programme's mission launched on October 17, 2002. Still in operation.

ESA led mission in collaboration with Russia, United States, Czech Rep. and Poland

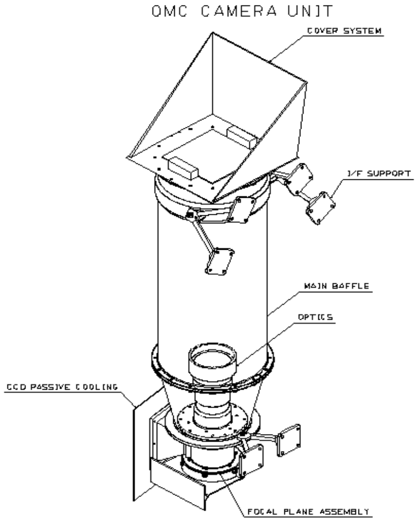
Czech participation based on Agreement

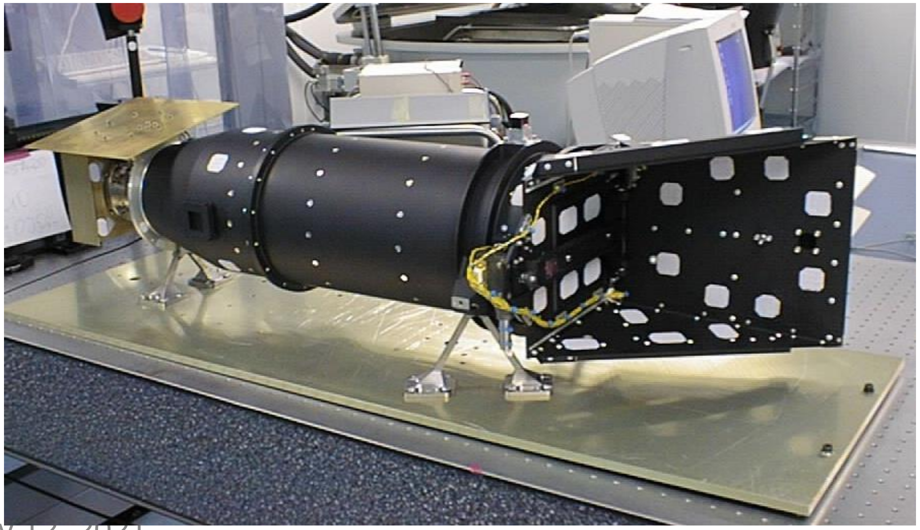
CR – ESA (from 2009 full ESA member)

Czech participation: OMC onboard camera, ISDC Science Data Centre, Scientific Analyses, cons membership

Optical Monitoring Camera (OMC)

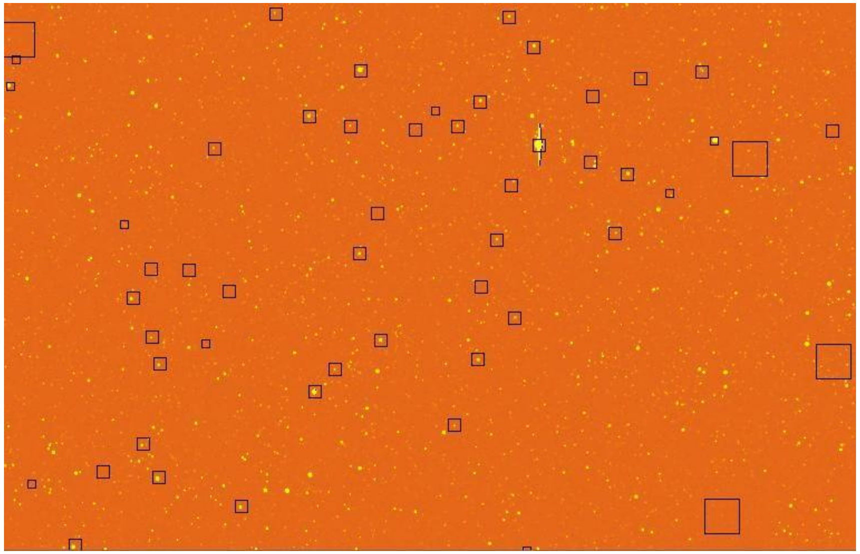
- **500 – 600 nm wavelength range**
- **CCD (2048 x 1024 pixels)**
- **5 x 5 degree FOV, 20” imaging**
- **Optical monitoring of high-energy sources**
- **17 kg**
- **Sensitivity: 18.2 mag in 1000 s**
- **Czech participation: onboard software, ISOC and ISDC software, simulators, test camera, tests, science**

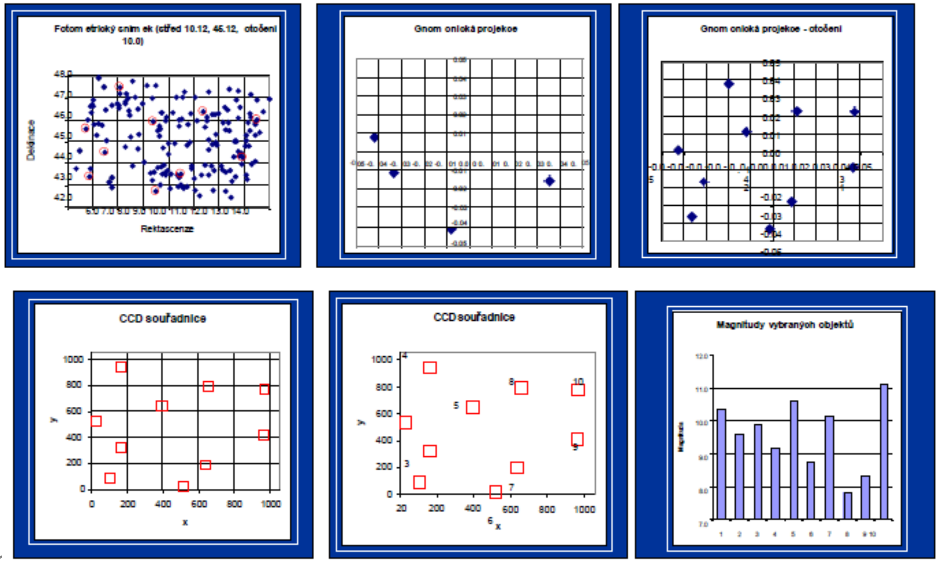




OMC Pointing Software OMC PS

- Developed by Věra Hudcová at AI Ondřejov, still in use
- Part of ISOC - Integral Science Operation Centre
- Generates telecommands sent to the satellite Controlls the OMC
- Selects objects observed. Transfer of up to 100 objects





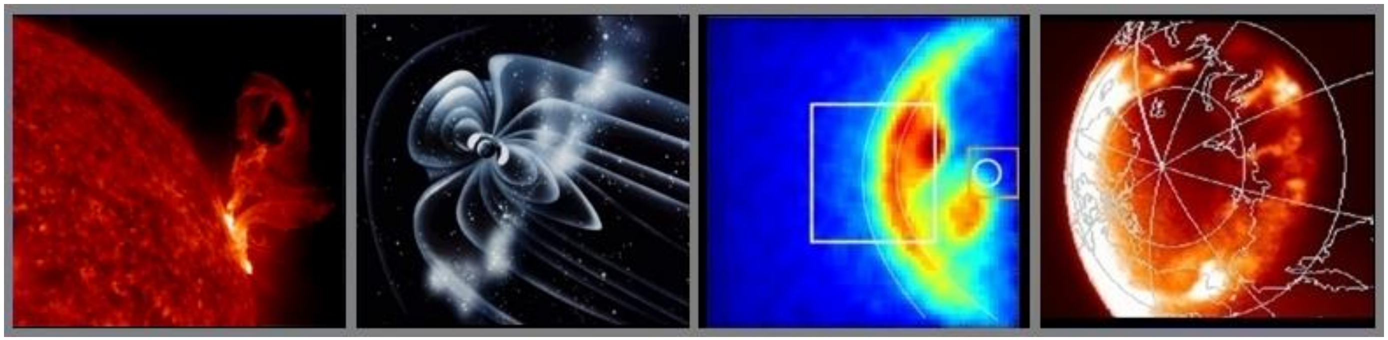
SMILE and THESEUS

- **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

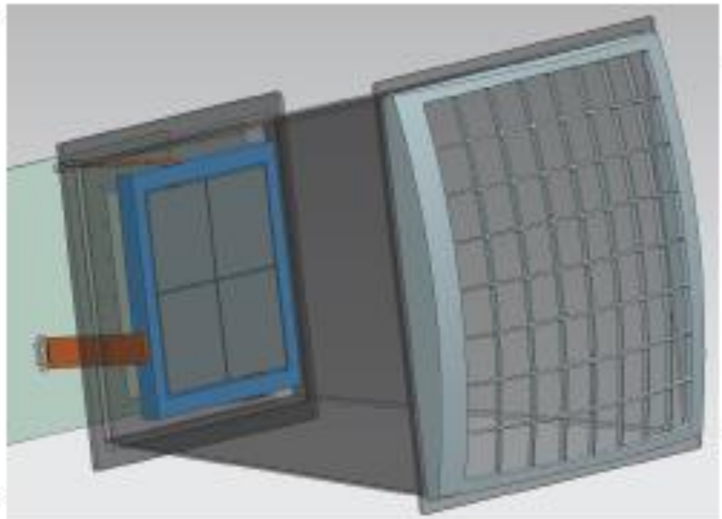
SMILE Soft X-ray Imager (SXI)

CCD Detector Plane

Photon counting

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

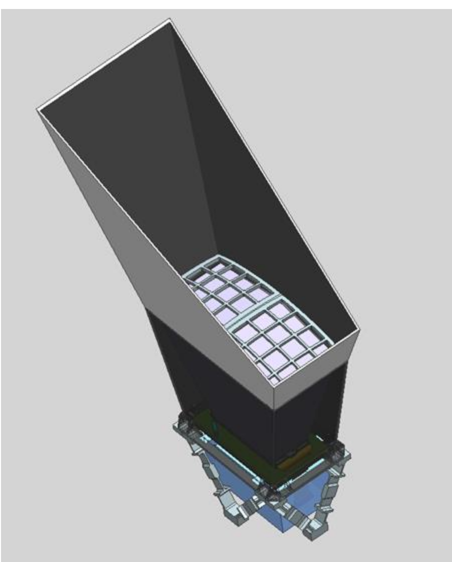
Medium energy resolution
~50 eV FWHM at 500 eV

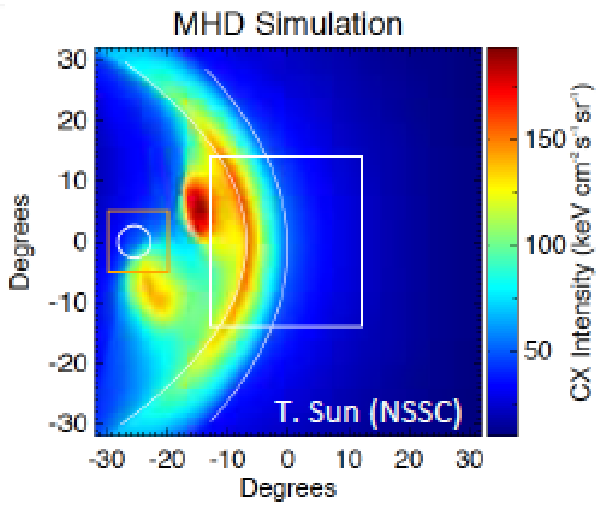


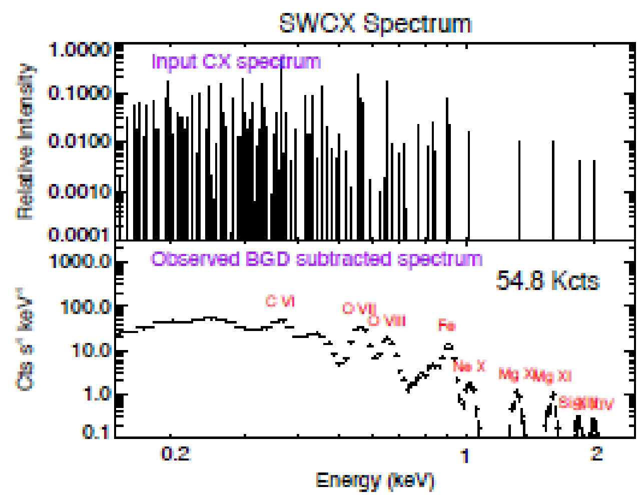
Lobster-eye Micropore Optic

Ultra-wide field of view
~25°x25°

Low Mass
~ 1kg optic array



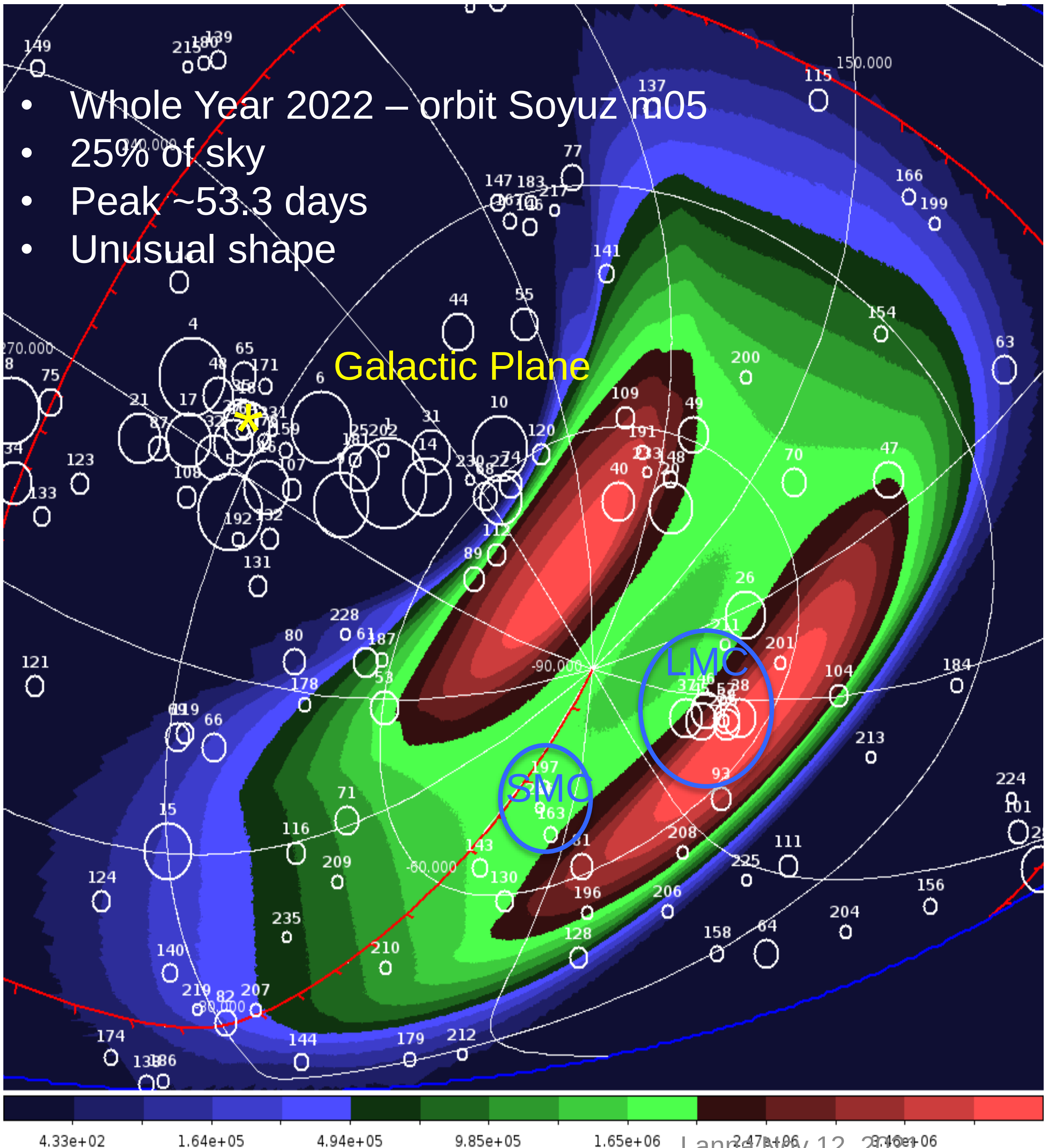




Lanna Nov 12, 2021

S. Sembay, Leicester Univ., UK

- Whole Year 2022 – orbit Soyuz m05
- 25% of sky
- Peak ~53.3 days
- Unusual shape



Many bright X-ray sources

Many well-known calibration sources & IACHEC[1] standard candles (1ES0102, N132D, PKS2155, Zeta Puppis, AB Dor, LMC-X2, LMC X-3, Vela Pulsar…)

Analysis of all RASS sources >2 cps (237) over full year of SXI observations (m05, S8, a0):

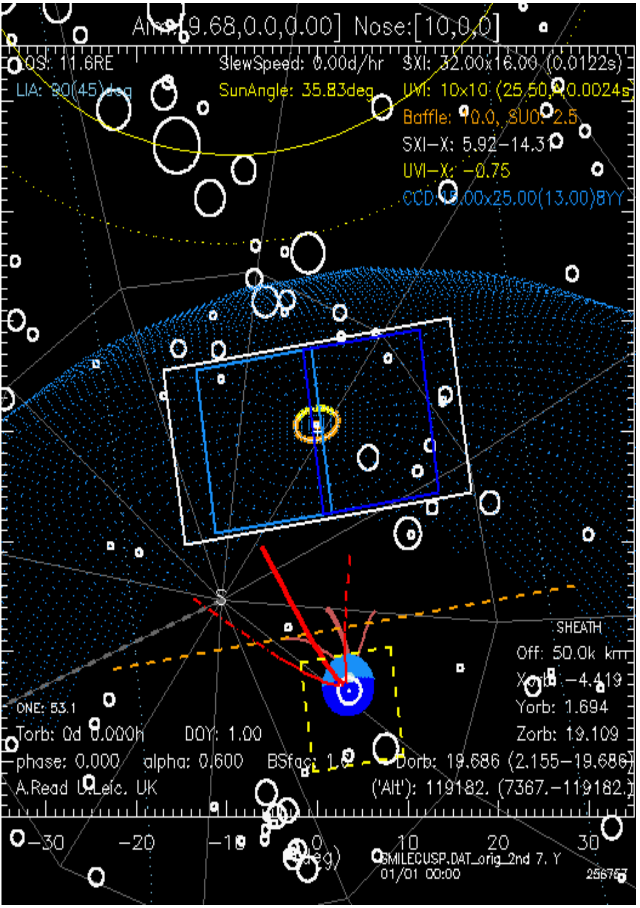
- Only occurrences of 6+ sources in the SXI FOV when observing the LMC…

SXI Sky exposure

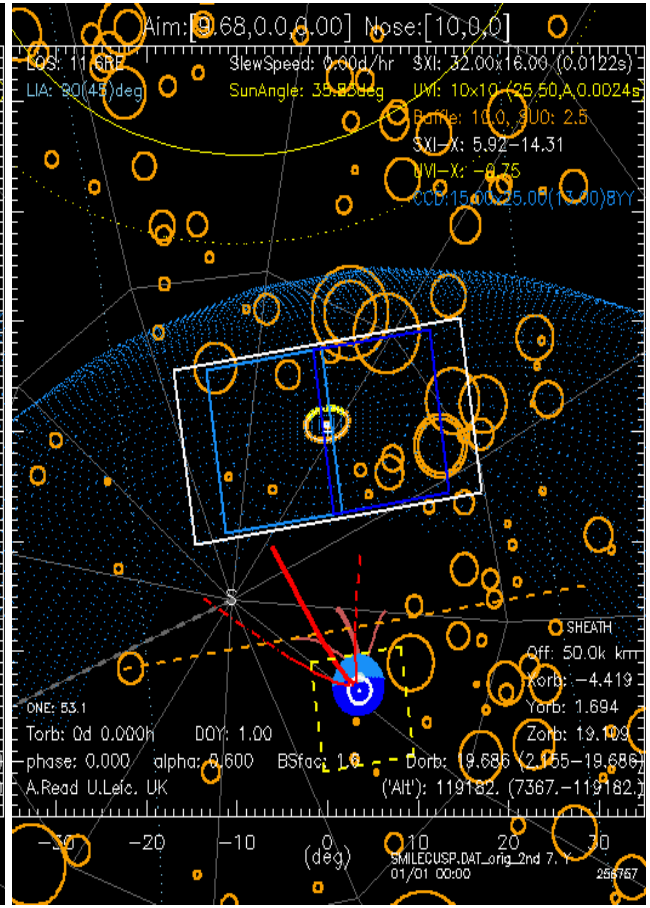
1: IACHEC: International Astronomical Consortium for High-Energy Calibration

Cosmic sources passing through the SXI FOV

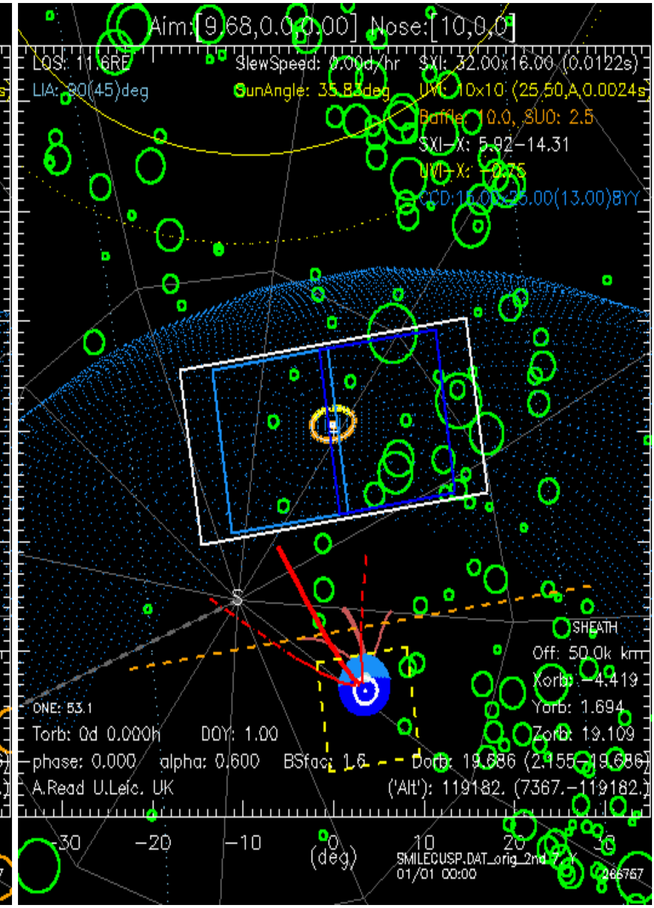
X-ray sources



Optical stars



UV sources

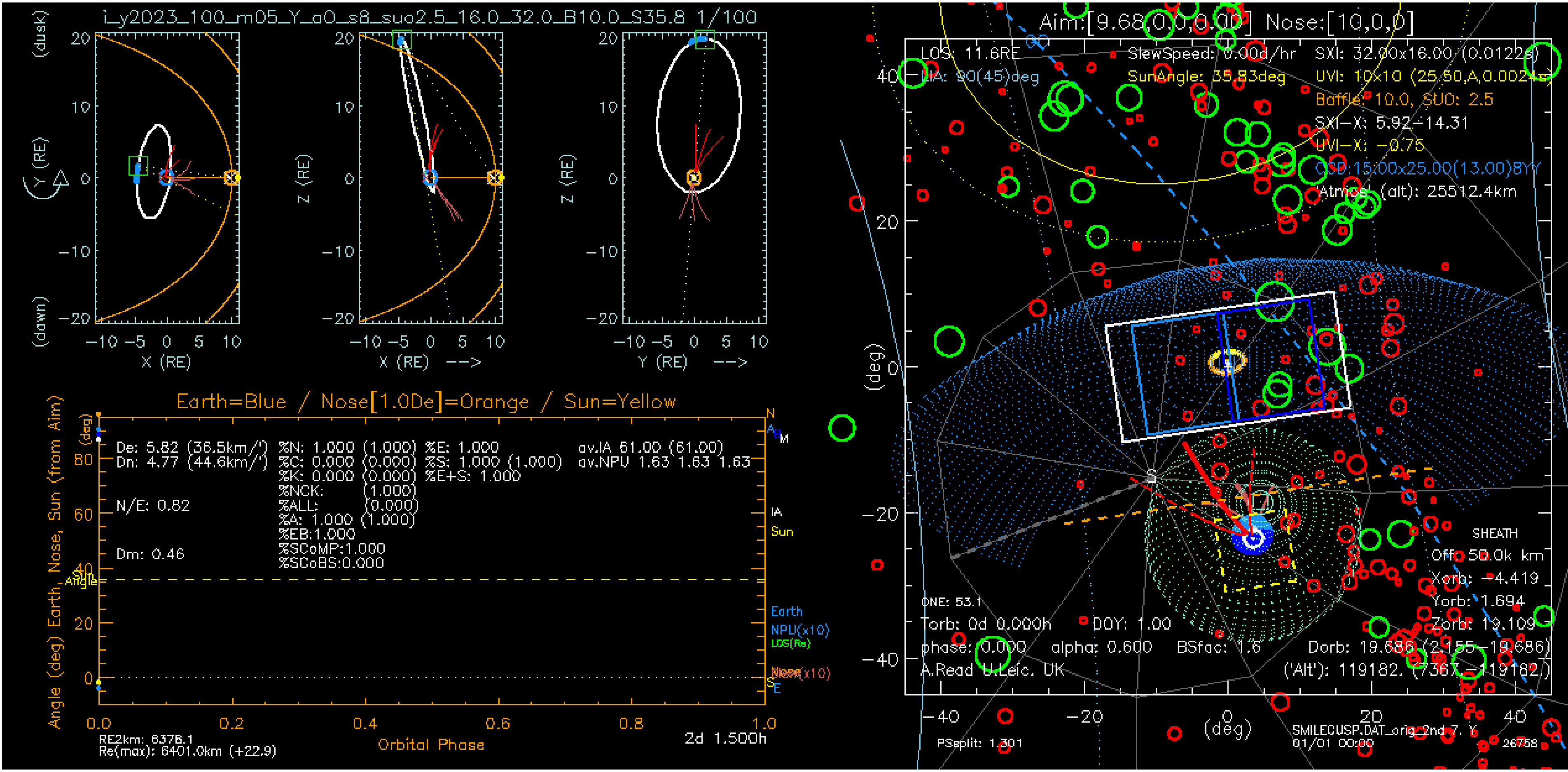


RASS catalogue
PSPC count rate > 1 cps

Bright Star catalogue
V mag brighter than 4[th] mag

TD1 catalogue
1565Å flux > 2e-10 cgs

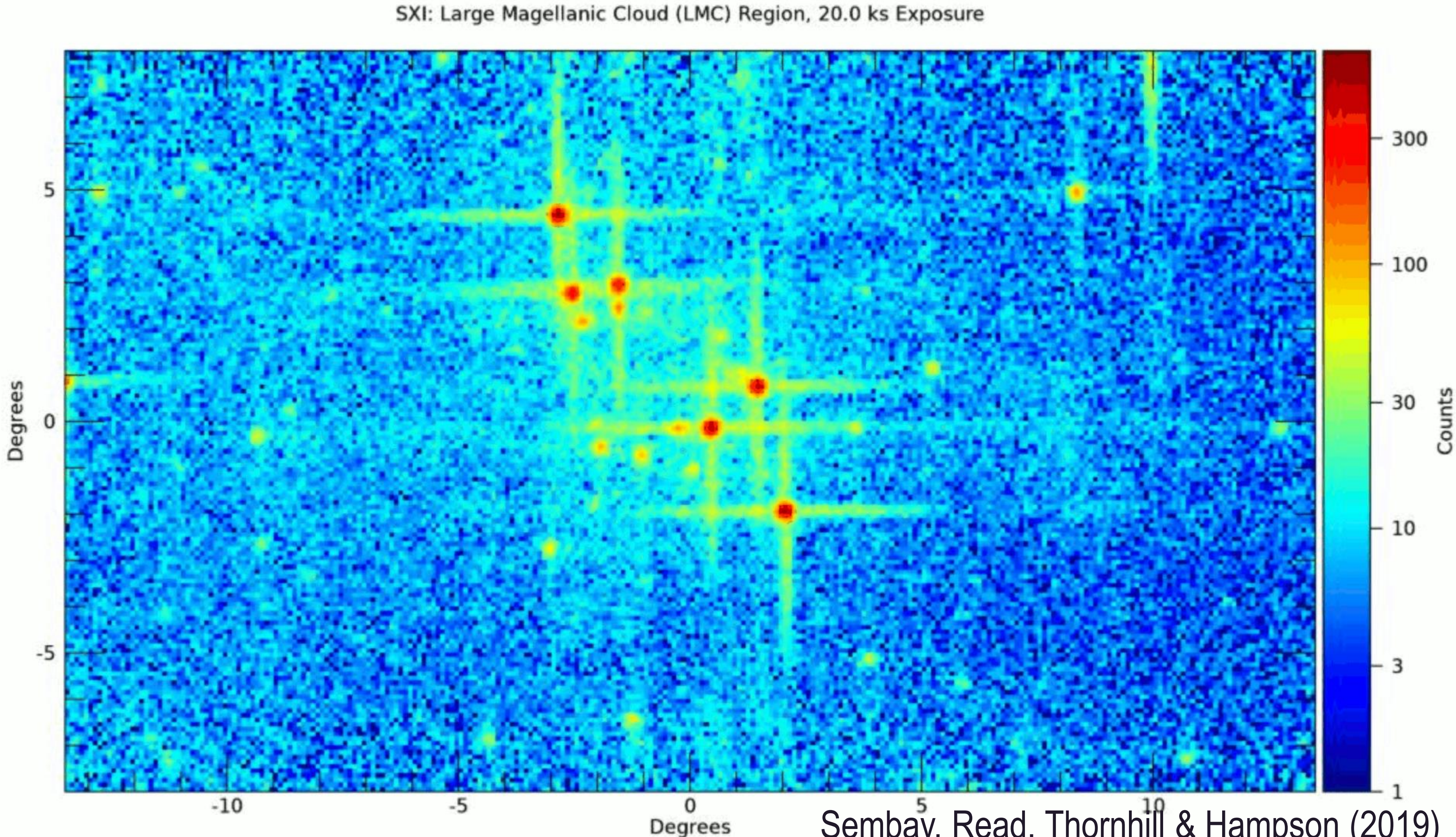
MOVIE SHOWING UV STARS AND PLASMASPHERE



Red + Green (>2x10^{-9} ergs s^{-1} cm^{-2} $Å^{-1}$) circles are UV (B stars) from TD1 catalogue

R_E sphere around Earth represents plasmasphere (4 R_E radius within SXI FOV ~23% of SXI on-time)

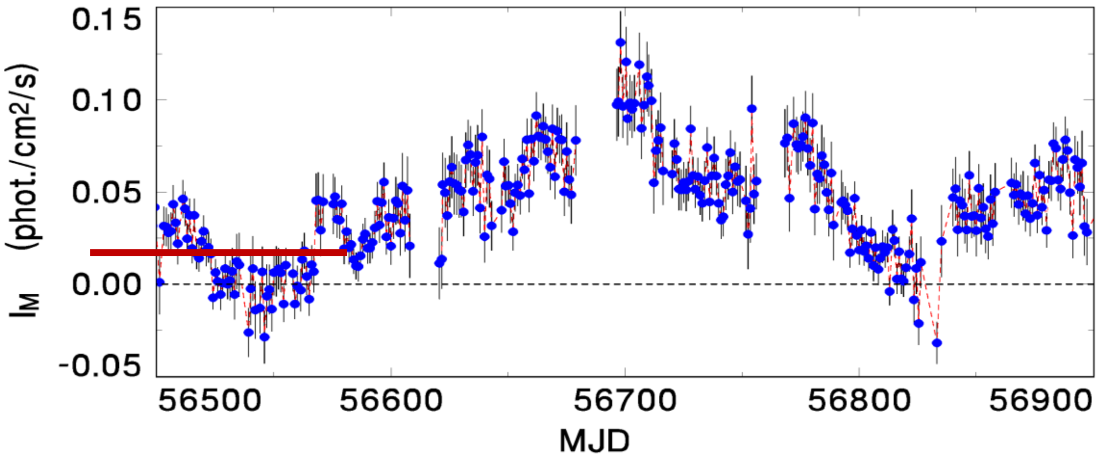
Detection of cosmic sources with SXI/SMILE



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)

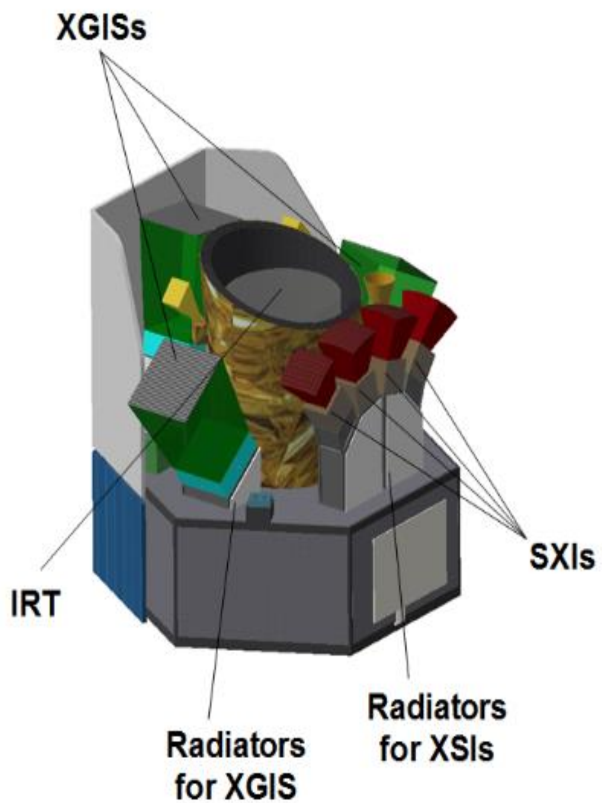
- SMC X-1: superorbital X-ray modulation, persistent accretion disk (neutron star+B0 supergiant)
- LMC X-2: low-mass X-ray binary, neutron star accretor, Z-source
- LMC X-3: high-mass X-ray binary, black hole
- SMC X-2: transient X-ray pulsar, neutron star+Be binary
- SMC X-3: transient X-ray source,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

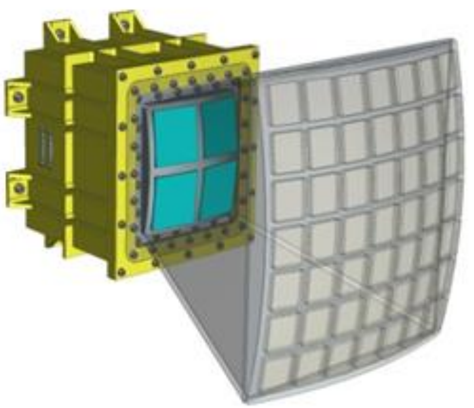
ESA THESEUS mission: ESA M5 call

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





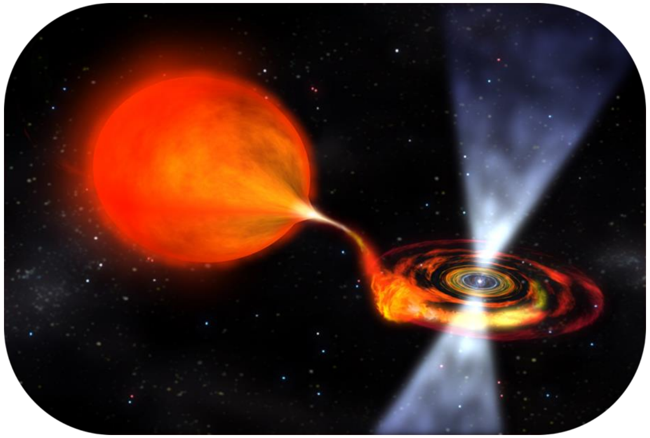
In final competition not selected, but consortium will try to submit again

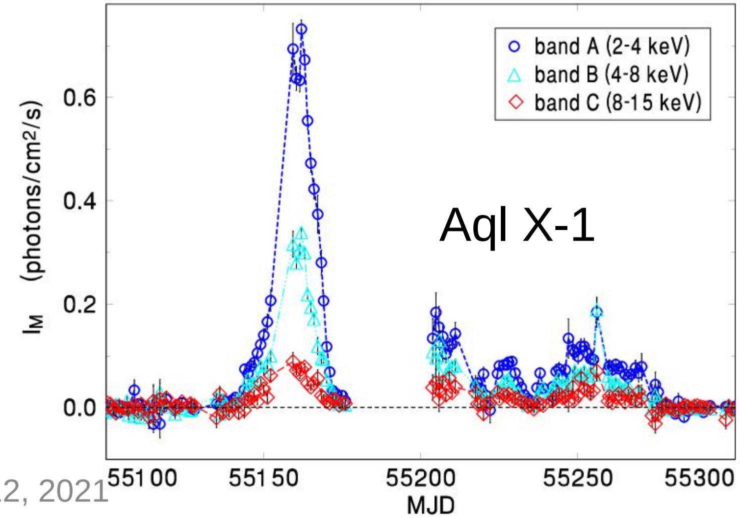
LEO (< 5°, ~600 km)
Rapid slewing bus
Prompt downlink

THESEUS, Cataclysmic Variables and Supersoft X-ray sources: our scientific contribution

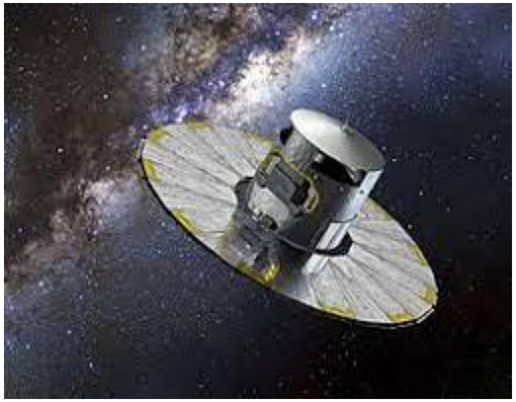
- **Search for spectral variations**
- **A very important role of the spectral region of the X-ray monitor – the soft X-ray activity (e.g. ASM, MAXI) of a given object can be very different from that in the hard X-ray band (BAT).**

- **Transitions between the states of activity: large differences between the light curves in various X-ray bands (structural changes of the emitting regions).**

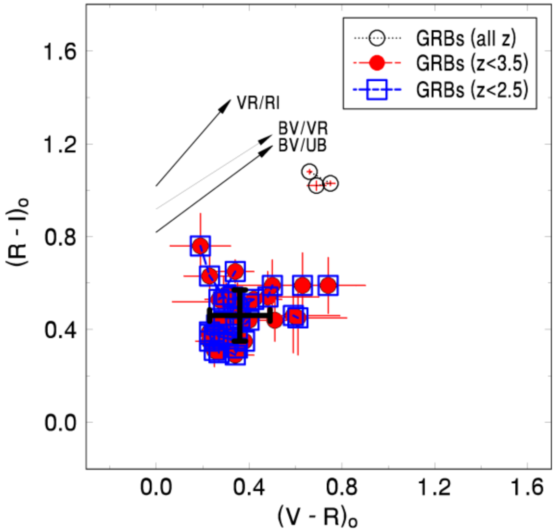




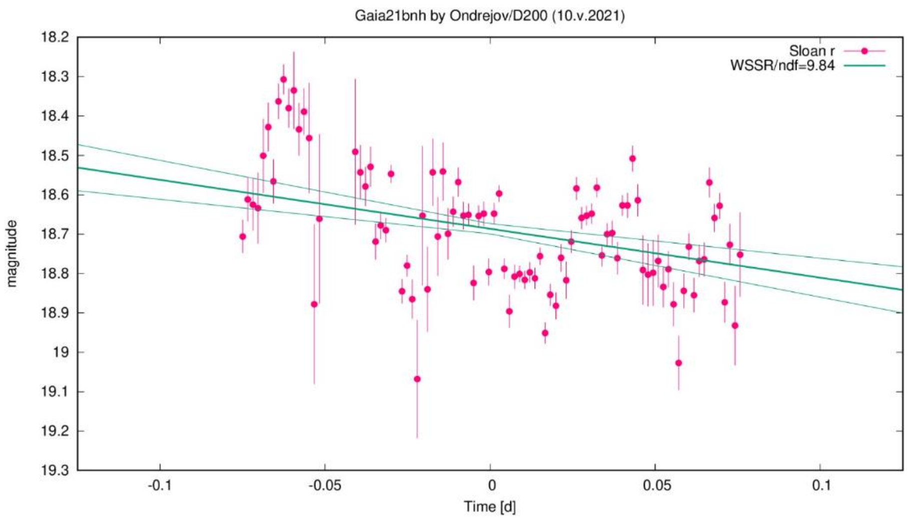
ESA Gaia

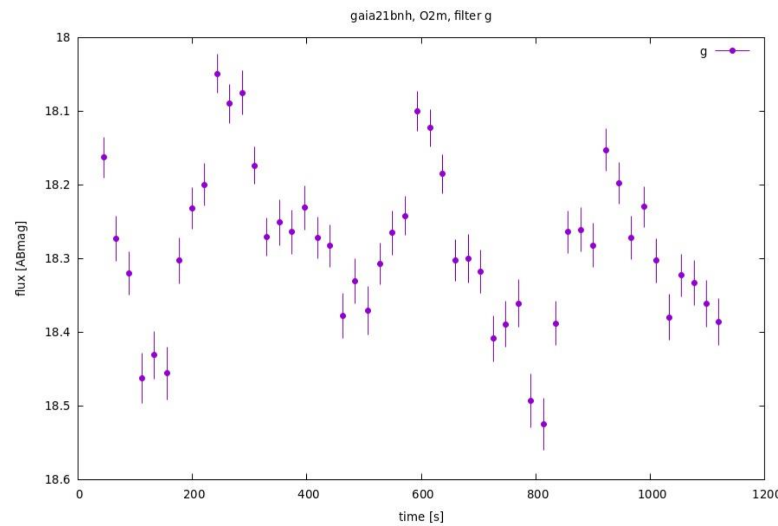


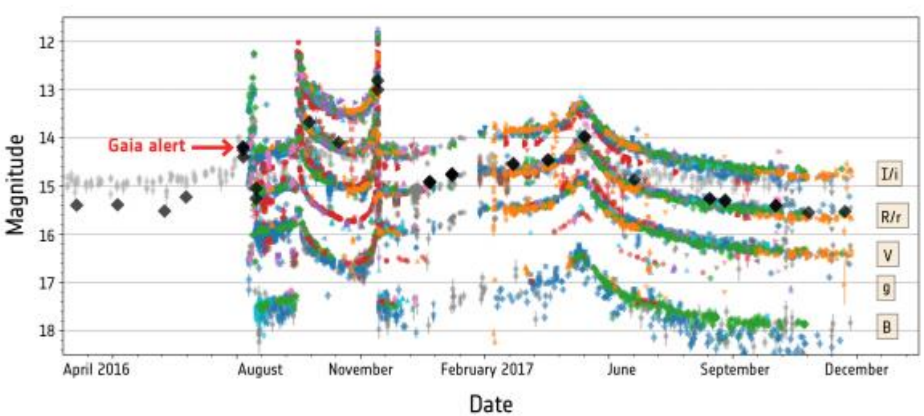
- Participation in Gaia Photometric Science Alerts system by providing follow-up by our robotic telescopes
- With emphasis on microlensing events, blazars and cataclysmic variables, mostly new and with very large amplitudes
- Use of Gaia data with emphasis on RP,BP for study of HE sources:
- Color-color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

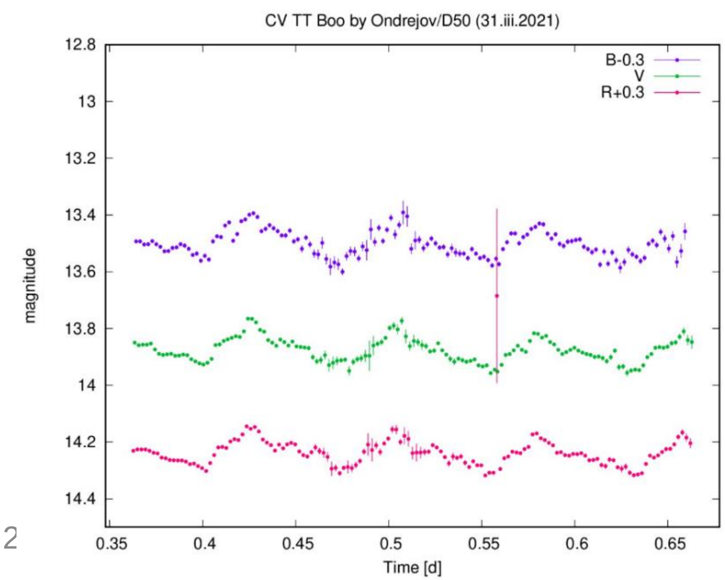


Examples of Gaia photometric alerts observed by our RTs









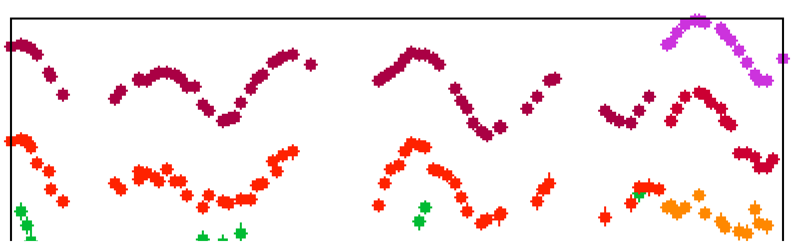
Recently 3 RTs:
BART, D50, SBT

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

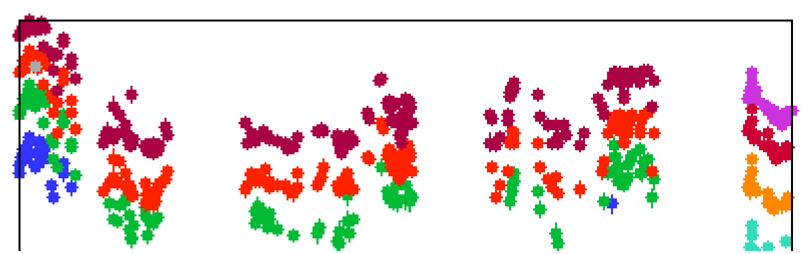
Ground based support: robotic telescopes

- **More than 50 targets in the list for continuous monitoring, mostly INTEGRAL HE sources, blazars, CVs, and newly detected Gaia alert sources. Automated data pipeline developed by M. Jelinek.**
- **Satellite observing campaigns. GRBs alerts follow-up.**

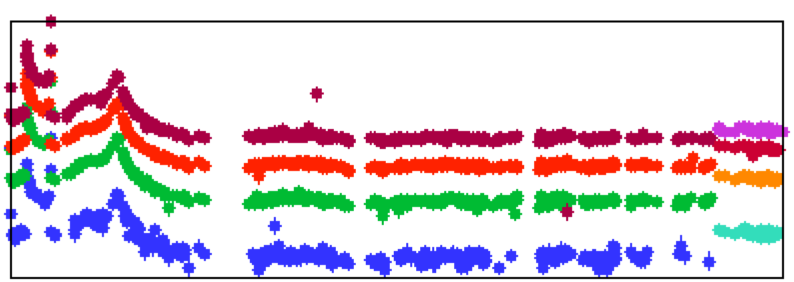
Gaia18cnz by D50 (id 01144)



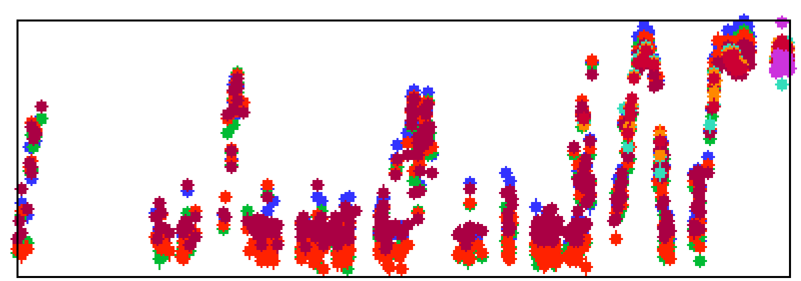
Gaia18cmy by D50 (id 01145)



Gaia16aye by D50 (id 01111)



KR Aur by D50 (id 01104)



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**

The End

Thanks for your attention