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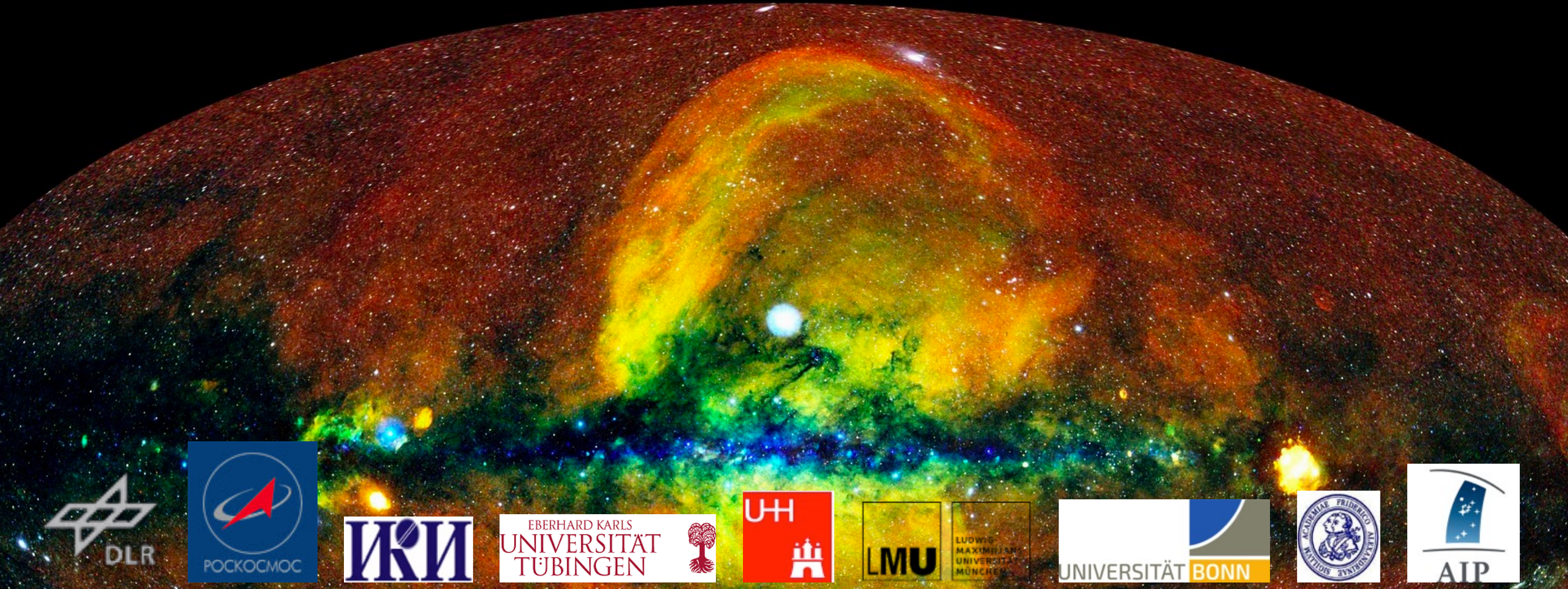
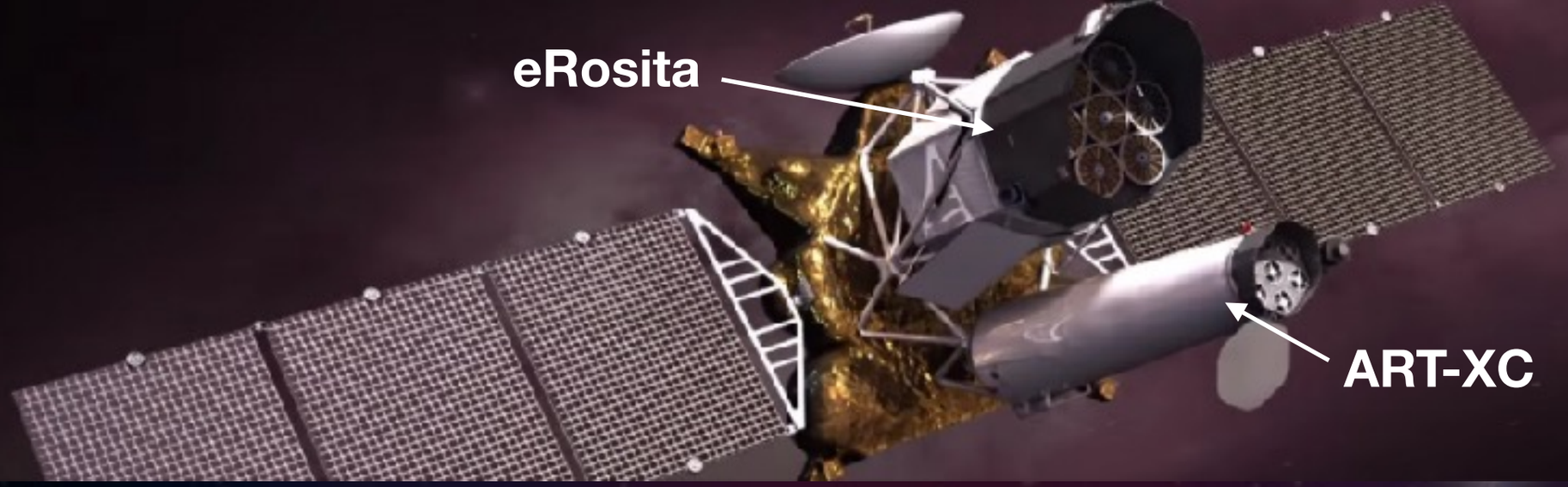
INSTITUTE FOR ASTRONOMY
AND ASTROPHYSICS
TÜBINGEN, GERMANY

THE BEAUTY OF THE HIDDEN UNIVERSE

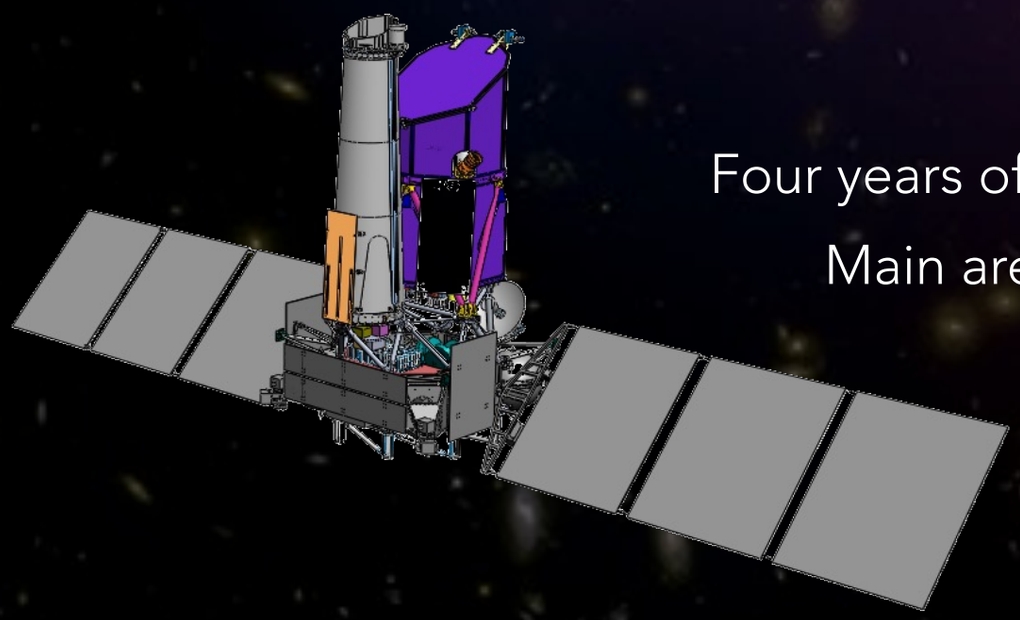
THE eROSITA X-RAY SKY SURVEY





- extended Roentgen Survey with an Imaging Telescope Array -

- X-ray telescope on-board the Russian/German mission Spektrum-RG
- eROSITA is a German instrument, developed and manufactured at the MPE Garching in collaboration with the universities of Tübingen, Hamburg, Potsdam, Bonn and Bamberg
- There is also a Russian instrument on-board Spektrum-RG: ART-XC
- In development since: 2005
- Successfully launched: 13.7.2019
- Orbit: L2 Halo Orbit



Scientific Goals:

Four years of all-sky survey in X-rays, then 2-3 years pointed observations

Main area of interest: cosmology, structure formation in the universe

Observe 100.000 clusters of galaxies at different redshifts

DAS SPEKTRUM DES LICHTS

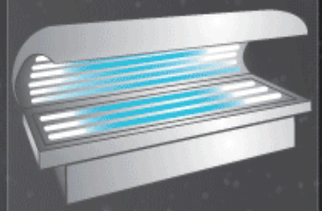
Sichtbar

RADIO

MIKRO

INFRAROT

UV

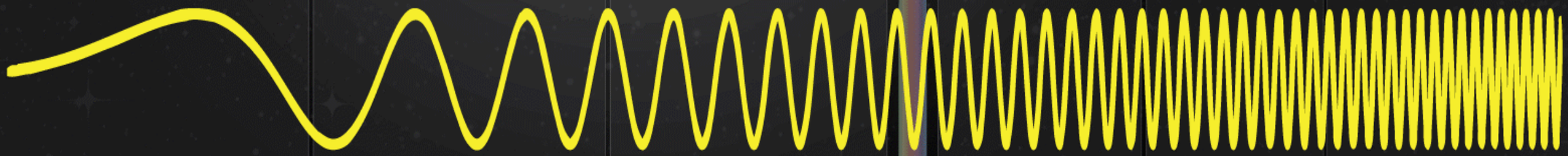


RÖNTGEN

GAMMA

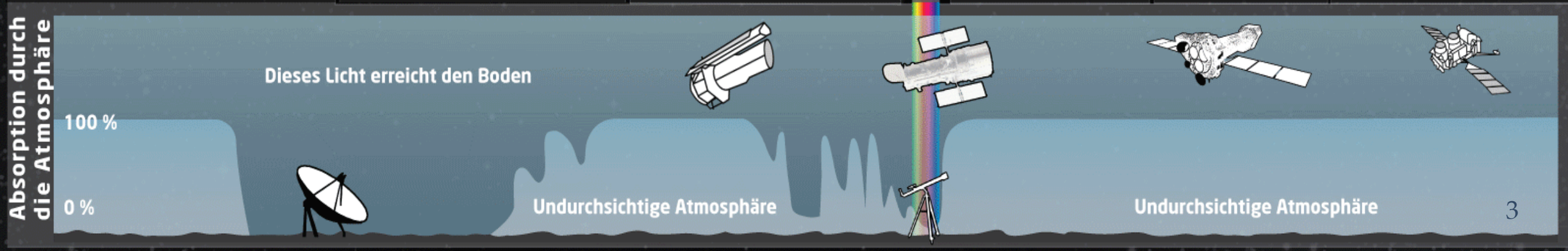
100kHz 10MHz 1GHz 100GHz 10THz 1PHz 100PHz 10EHz Frequenz

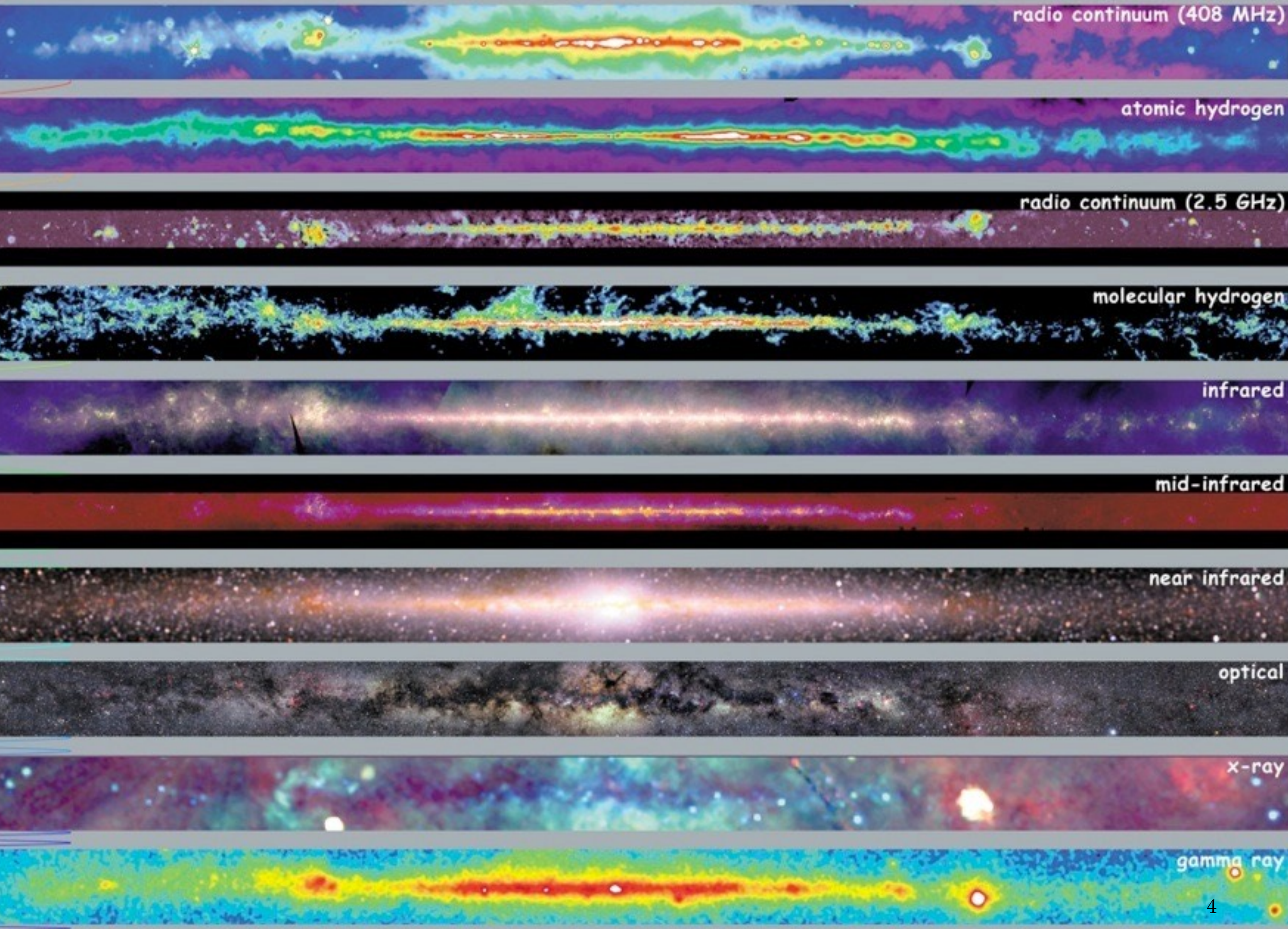
1MHz 100MHz 10GHz 1THz 100THz 10PHz 1EHz 100EHz

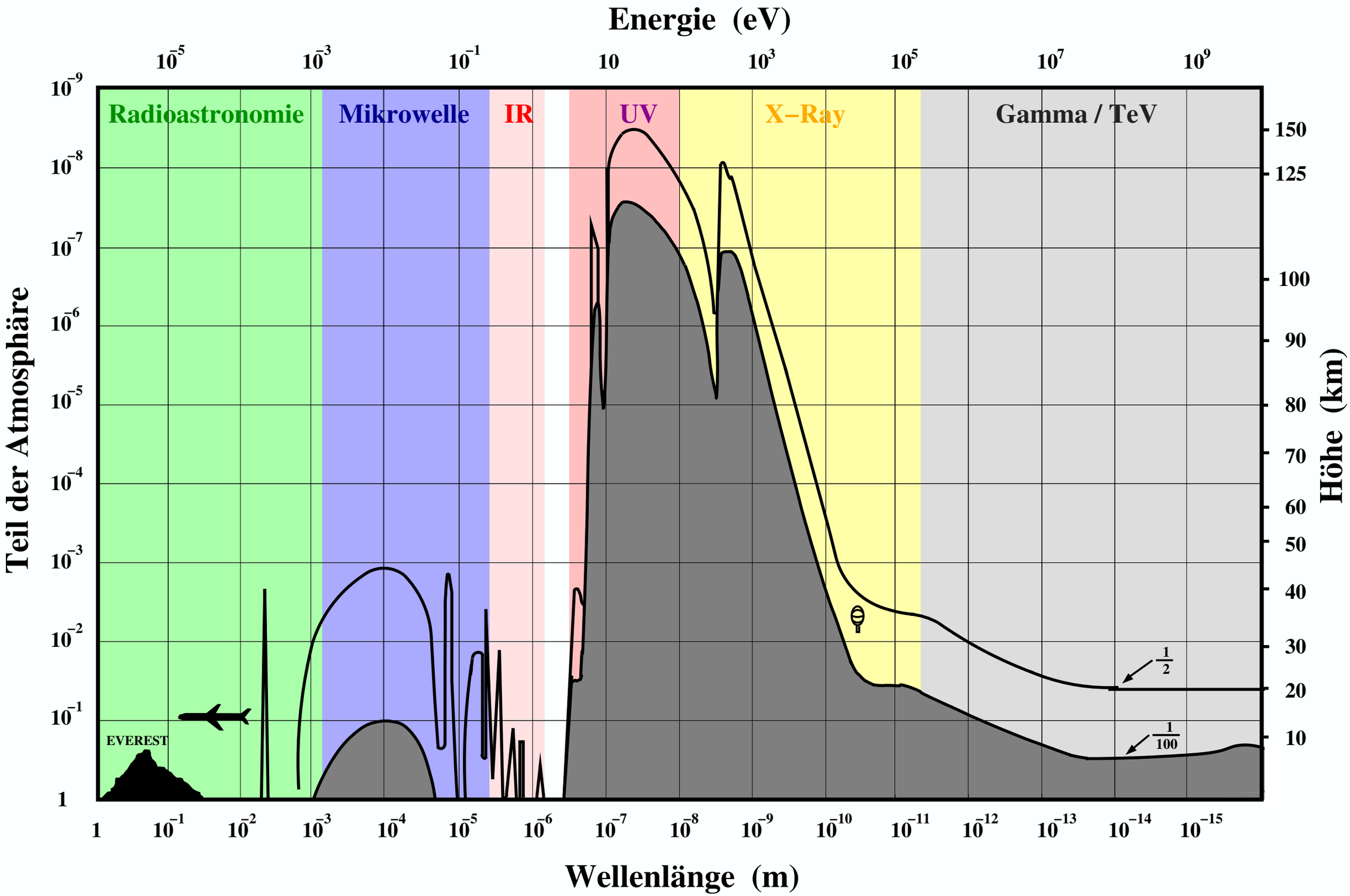


Wellenlänge

1km 100m 10m 1m 10cm 1cm 1mm 100µm 10µm 1µm 100nm 10nm 1nm 100pm 10pm 1pm 100fm



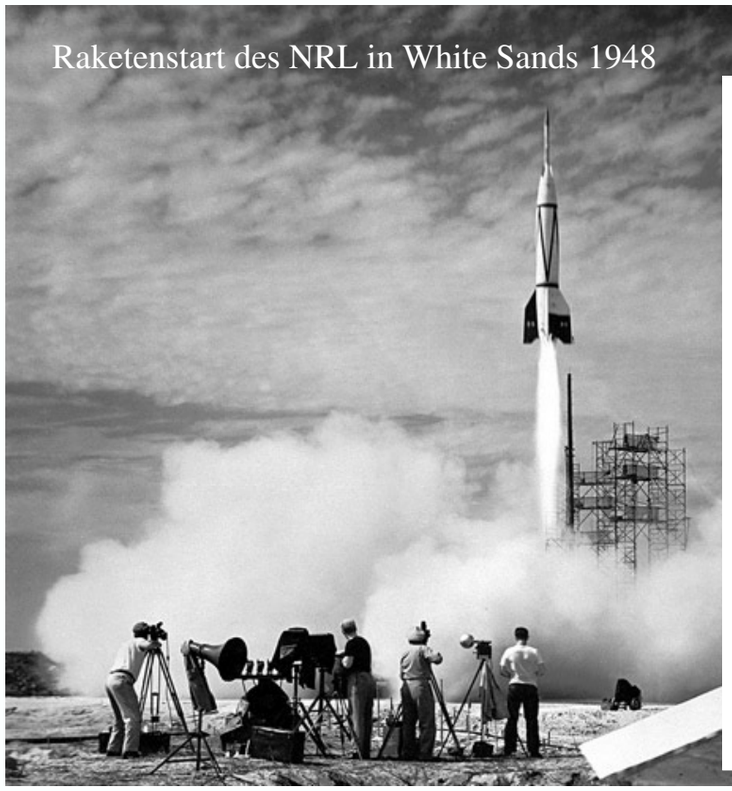

radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray

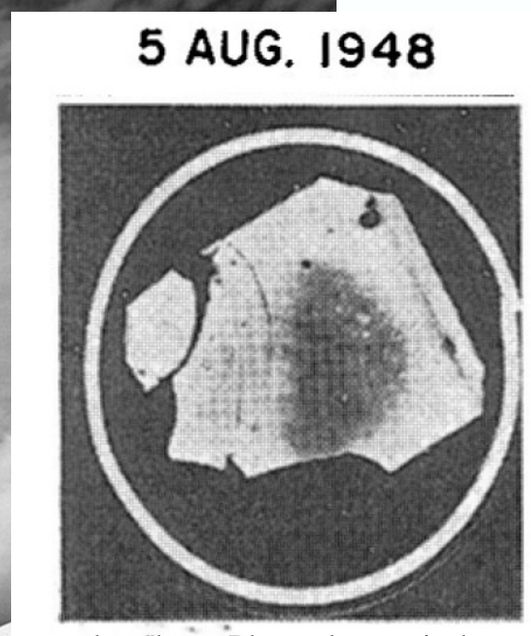


Absorption of radiation in Earth's atmosphere as a function of wavelength or energy. Below the black line less than 50% of the incoming radiation is seen. Inside the dark grey area less than 1% can be detected.

First X-rays seen from the Sun in 1948

Herbert Friedman
1916* – 2000 +





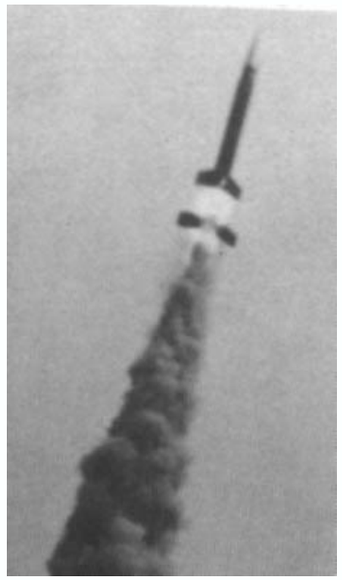
zerbrochene Photoplatte mit dem Röntgenstrahlennachweis der Sonne

Edward Hulburt
1890* – 1982 +

=> other stars will be too faint to be observed

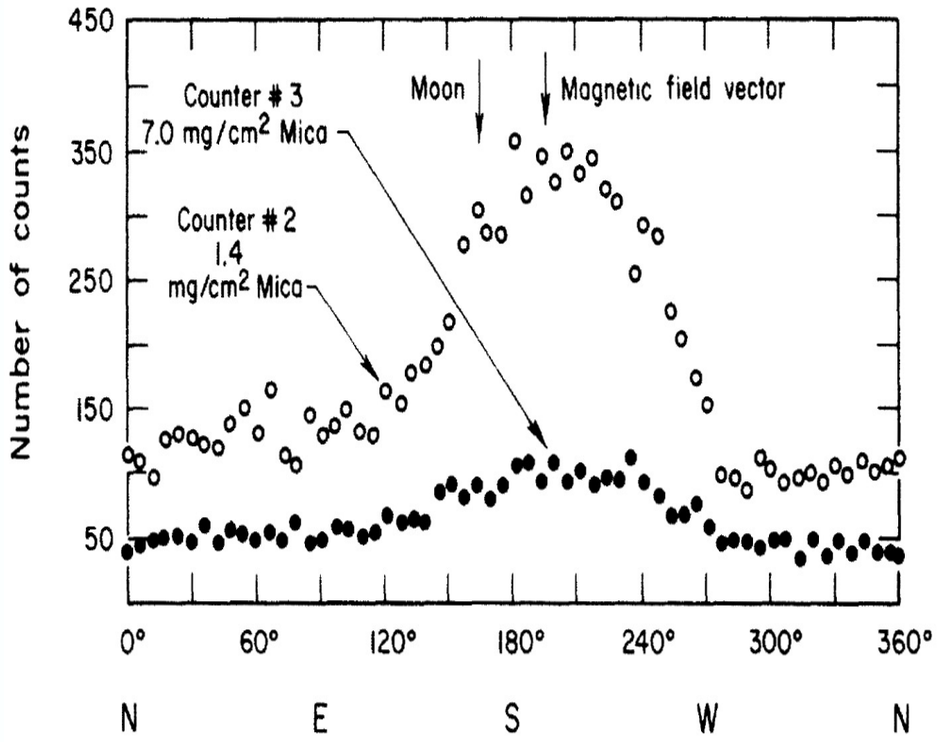
Discovery of Sco X-1 in 1962

Riccardo Giacconi
1931* - 2018



Start einer Aerobee 150 Rakete

Bruno Rossi
1905* – 1993 +



PHYSICAL REVIEW
LETTERS

VOLUME 9 DECEMBER 1, 1962 NUMBER 11

EVIDENCE FOR X RAYS FROM SOURCES OUTSIDE THE SOLAR SYSTEM*

Riccardo Giacconi, Herbert Gursky, and Frank R. Paolini
American Science and Engineering, Inc., Cambridge, Massachusetts

- 2018

and

Bruno B. Rossi
Massachusetts Institute of Technology, Cambridge, Massachusetts

(Received October 12, 1962)

Data from an Aerobee rocket carrying a payload consisting of three large area Geiger counters have revealed a considerable flux of radiation in the night sky that has been identified as consisting of soft x rays.

The entrance aperture of each Geiger counter consisted of seven individual mica windows com-

ter was placed in a well formed by an anticoincidence scintillation counter designed to reduce the cosmic-ray background. The experiment was intended to study fluorescence x rays produced on the lunar surface by x rays from the sun and to explore the night sky for other possible sources. On the basis of the known flux of solar x rays,

N E S W N

PHYSICAL REVIEW

VOLU ... BER 11

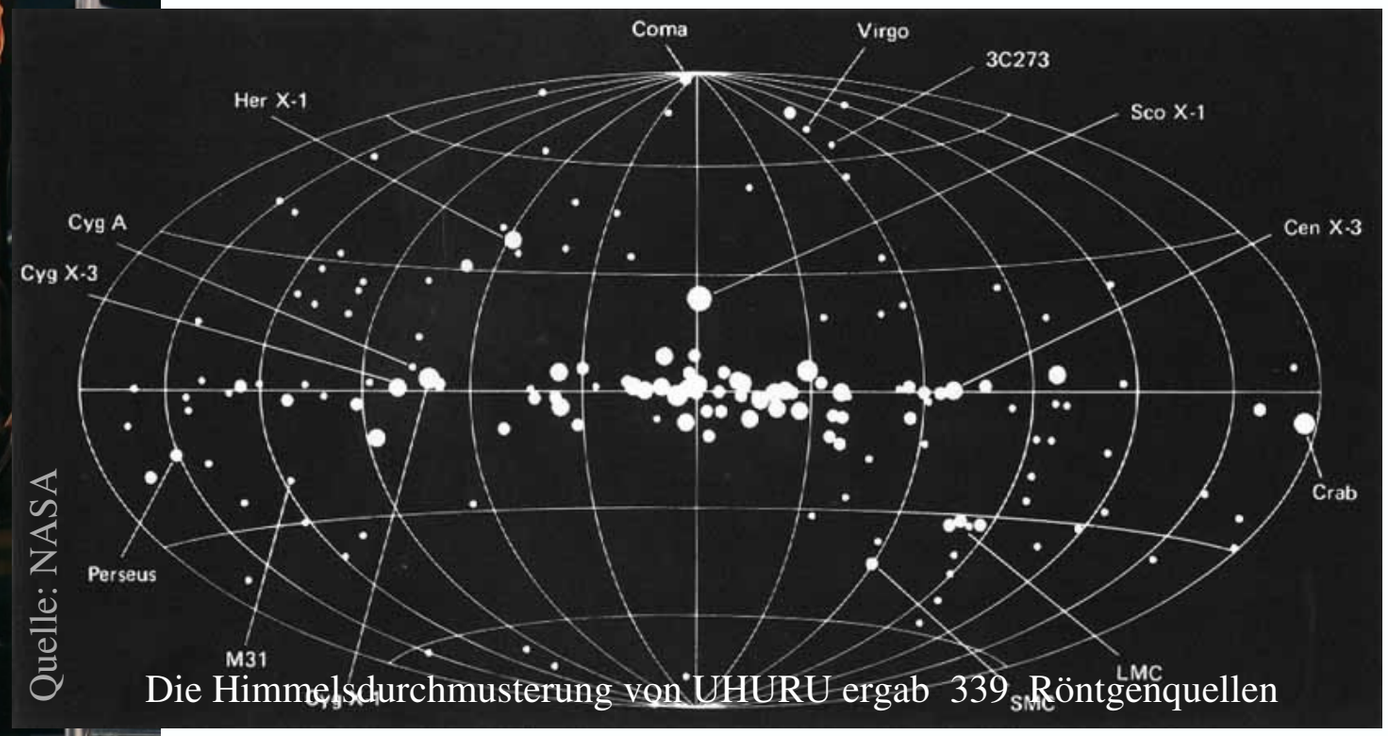
- 2018

Data fr... anticoinci-
load consi... reduce the
ters have... ent was in-
tion in the... oduced on
consisting... un and to
The enti... e sources.
consisted... x rays,

N E S W N

First X-ray satellite: UHURU sky survey (1970)

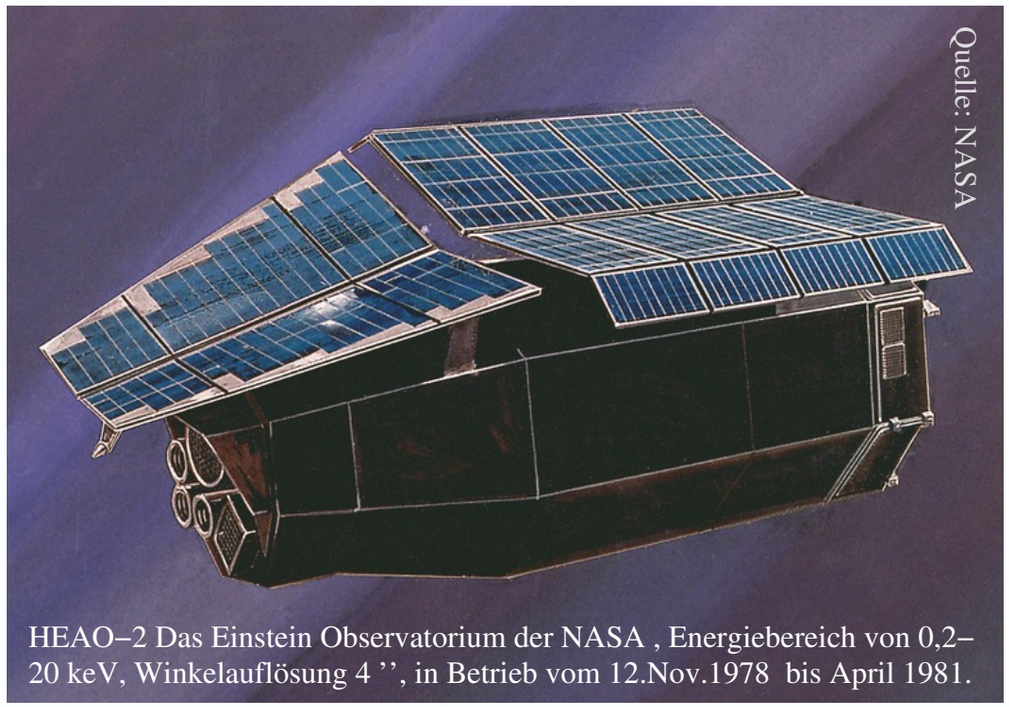
UHURU vor dem Start, zusammen mit Dr. Marjorie Townsend, der Namensgeberin von UHURU und Dr. Bruno Rossi.



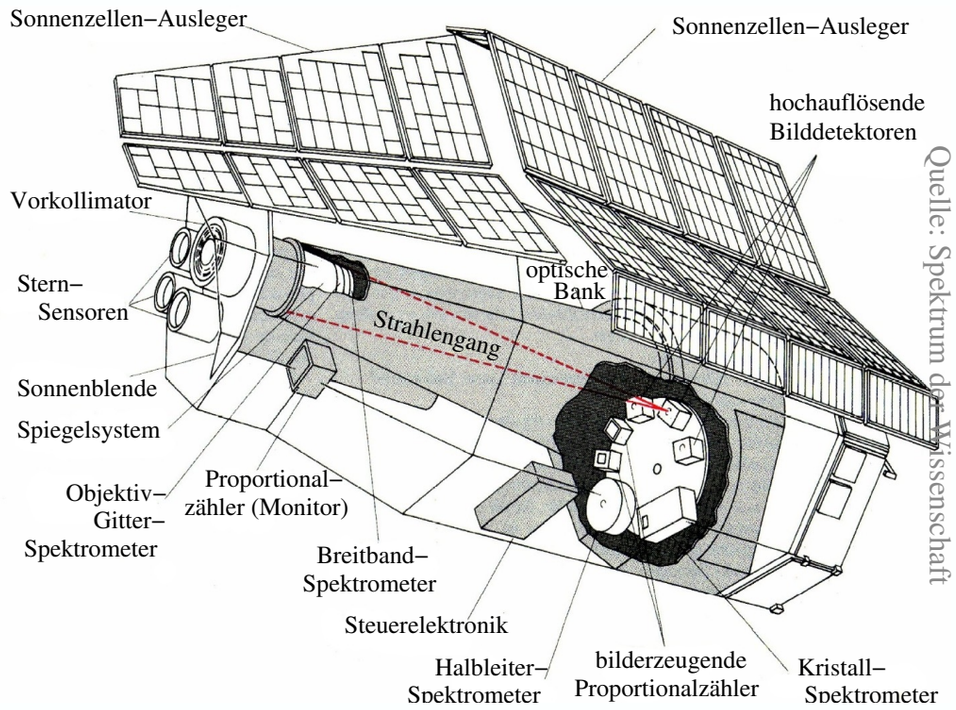
Die Himmelsdurchmusterung von UHURU ergab 339 Röntgenquellen

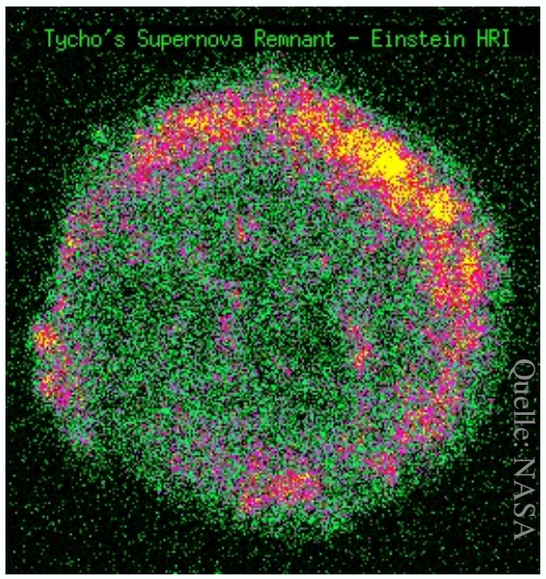
=> 339 sources, still with collimators (non-imaging)

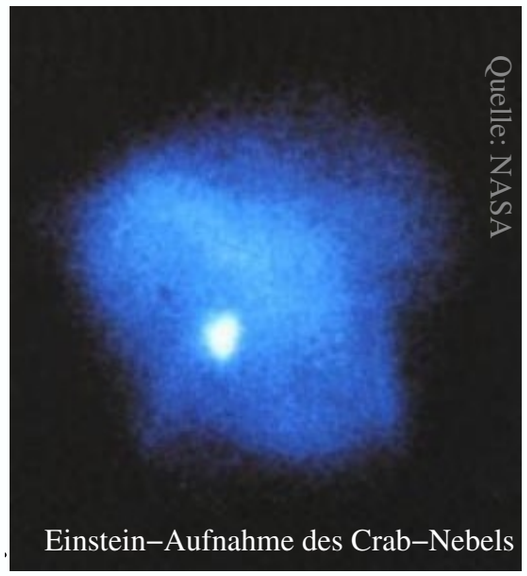
Imaging: HEAO-2 / Einstein (1978)



HEAO–2 Das Einstein Observatorium der NASA , Energiebereich von 0,2–20 keV, Winkelauflösung 4 ’’, in Betrieb vom 12.Nov.1978 bis April 1981.



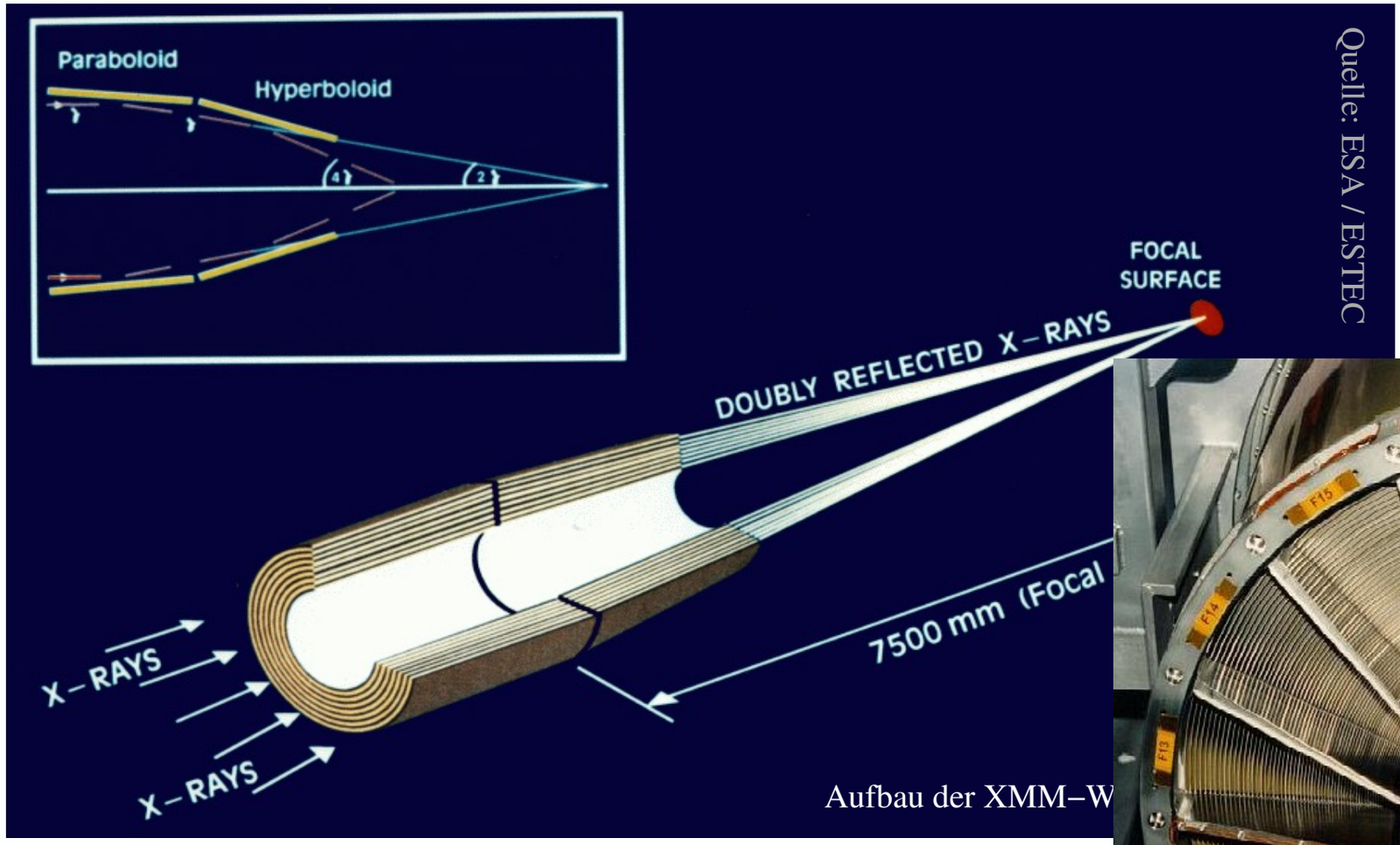




Einstein–Aufnahme des Crab–Nebels

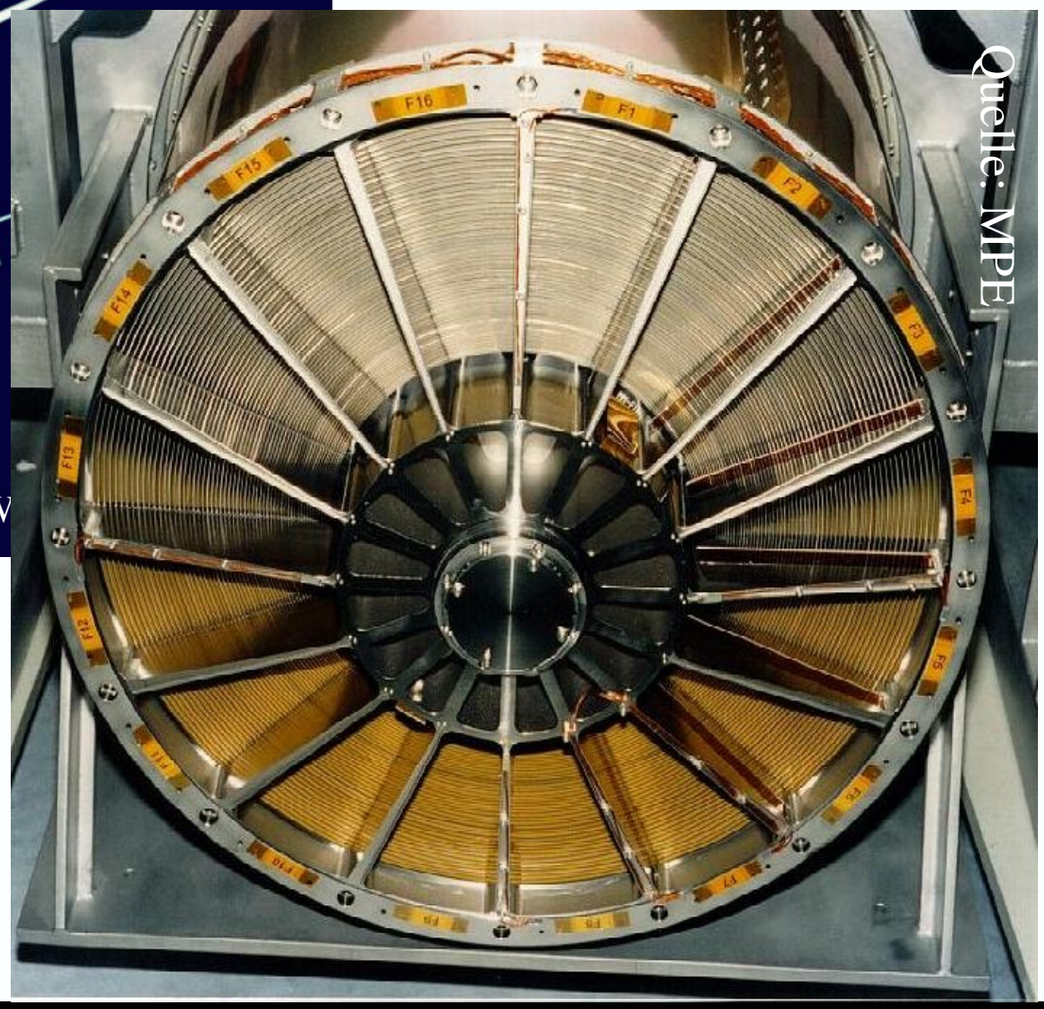
focusing from a large collection area onto a small detector also brings a huge gain in sensitivity

X-ray Optics



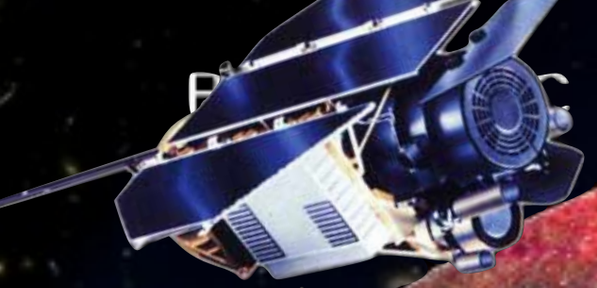
Quelle: ESA / ESTEC

Aufbau der XMM–W

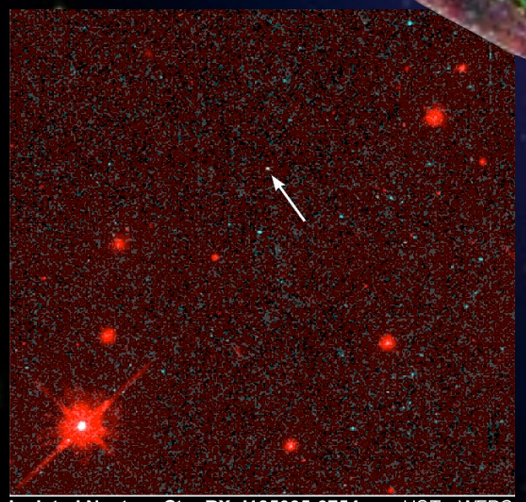


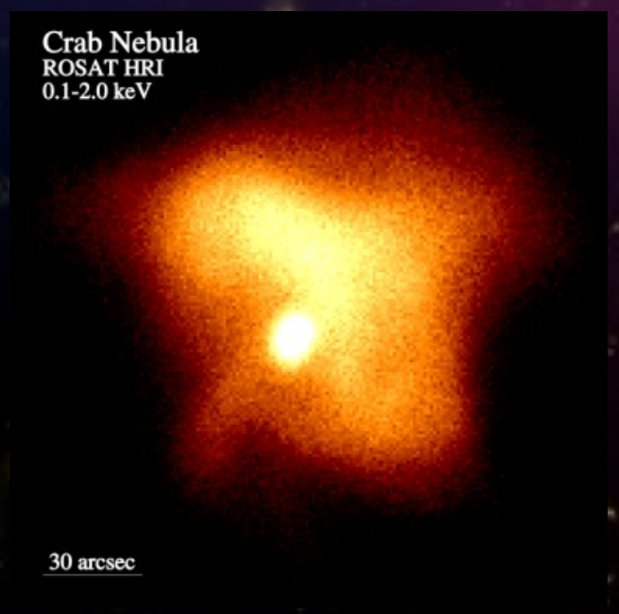
Quelle: MPE

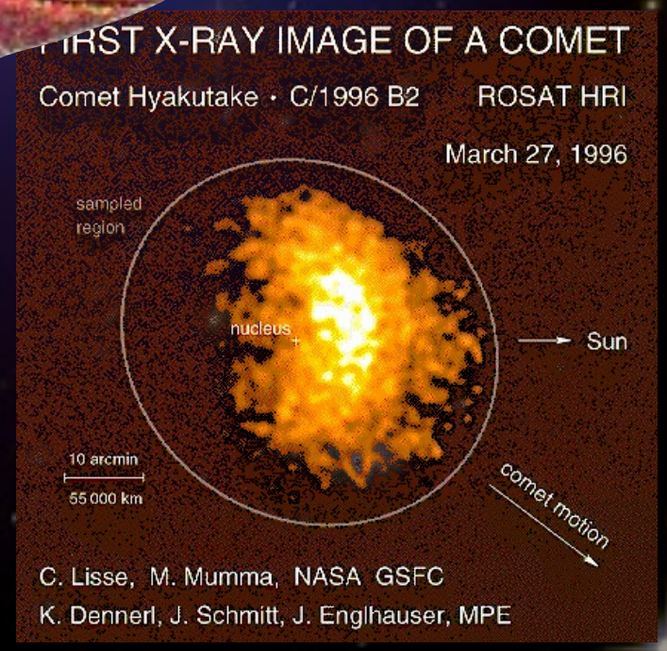
=> Wolter Type-I X-ray mirror nested shells



ROSAT (1990): very successful first imaging all-sky survey (145.000 sources)


Isolated Neutron Star RX J185635-3754 HST • WFPC





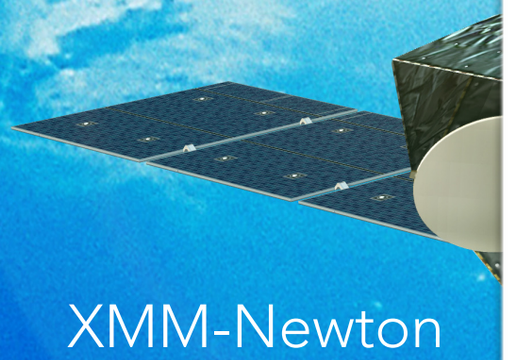
The Present Situation

XMM-Newton

Many small and large X-ray satellites have been (and are still) flown, each with a focus on different energy bands, imaging, timing, and spectroscopy studies.

- There are over a million detected sources of X-ray radiation in the sky. -

The Present Situation



XMM-Newton

Chandra

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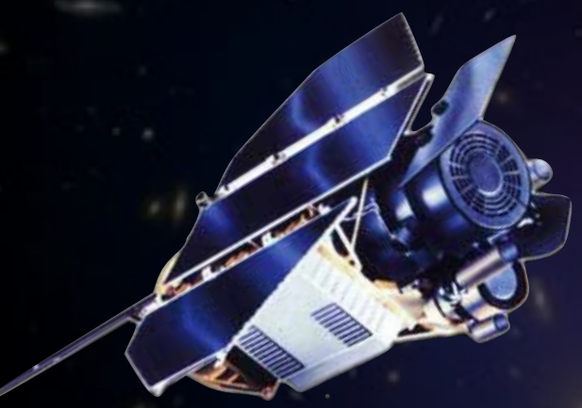
eROSITA mission history



ROSAT
1990-1998

First X-ray all-sky survey with an imaging telescope

Abrixas
1999
7 telescopes
goal: repeat the survey at higher energies

failed directly after launch

ROSITA: ABRIXAS on the International Space Station

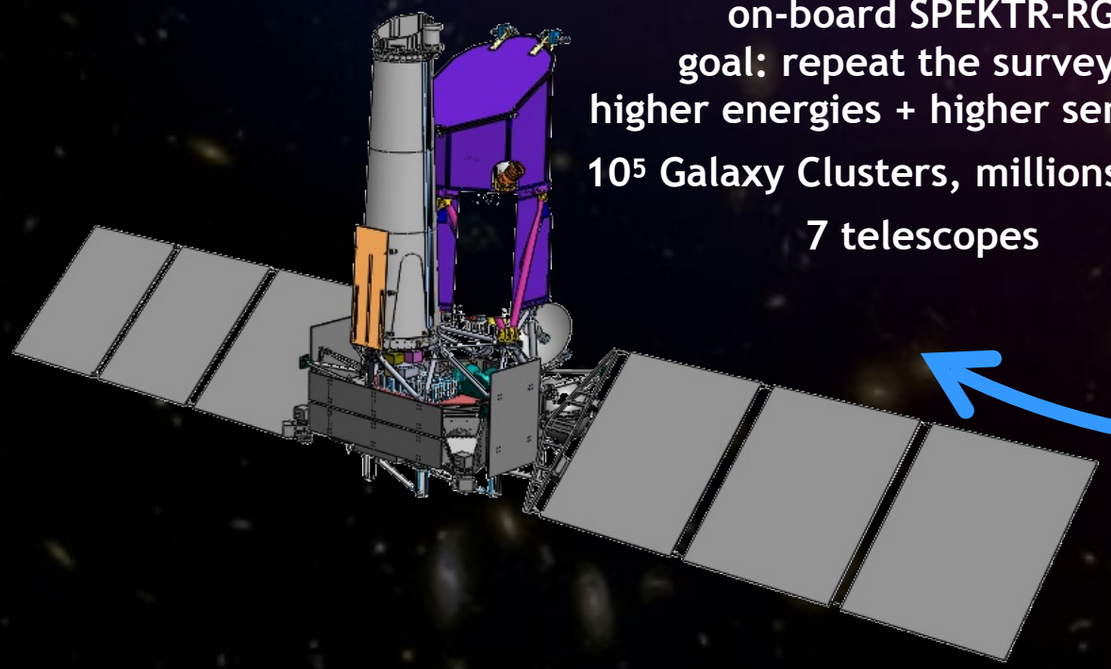
was not selected

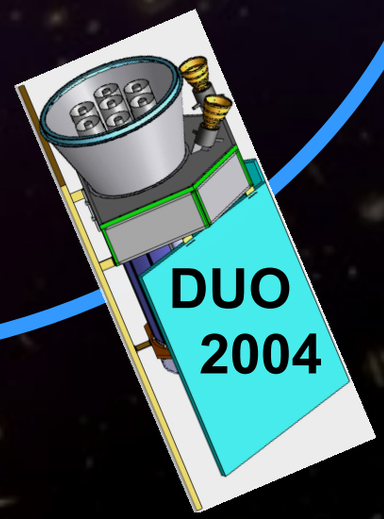
eROSITA

on-board SPEKTR-RG
goal: repeat the survey at higher energies + higher sensitivity

10^5 Galaxy Clusters, millions of AGN

7 telescopes

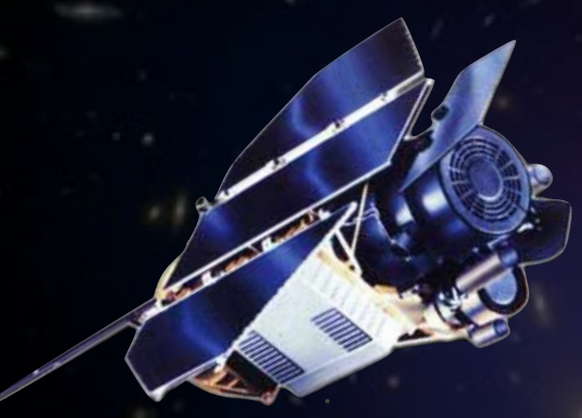




Dark Universe Observatory
2004
10^4 Galaxy Clusters

SMEX-proposal in the US was not selected

eROSITA mission history

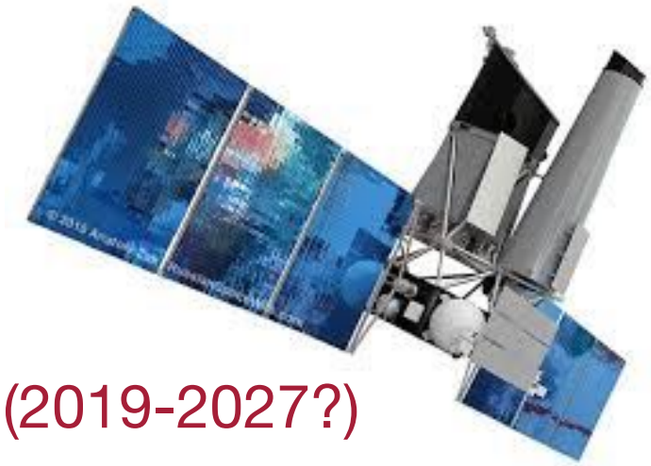


ROSAT
1990-1998

First X-ray all-sky survey with an imaging telescope

R (2011-2019)

Spectr-family



UV (2026+)

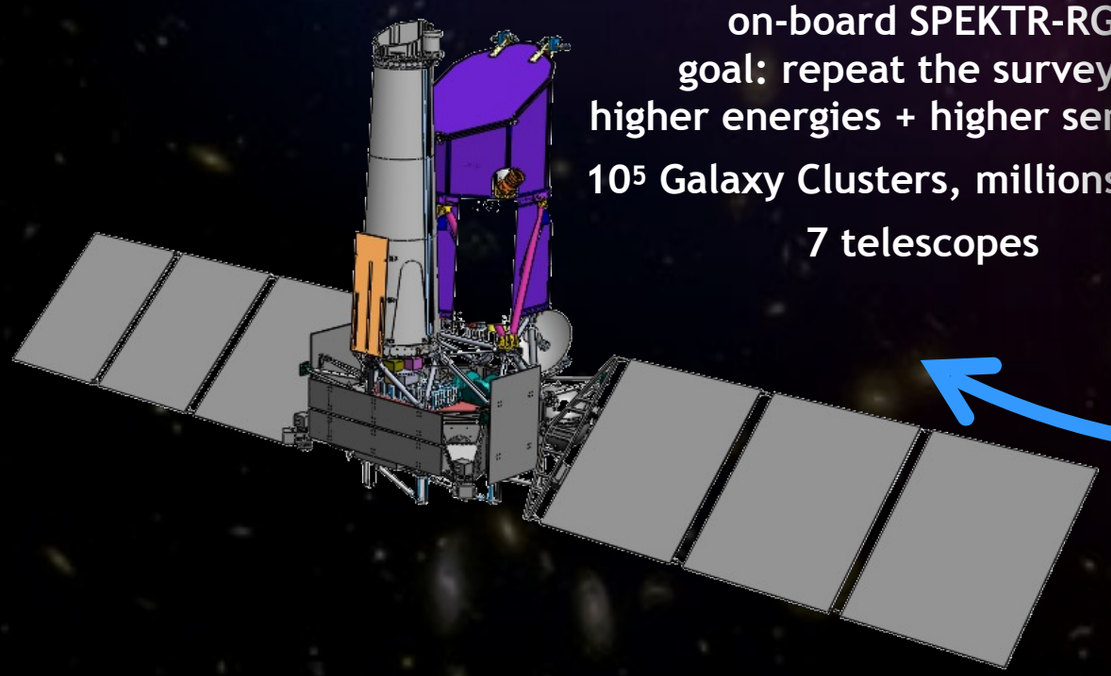
RG (2019-2027?)

eROSITA

on-board SPEKTR-RG
goal: repeat the survey
higher energies + higher ser

10^5 Galaxy Clusters, millions

7 telescopes



at

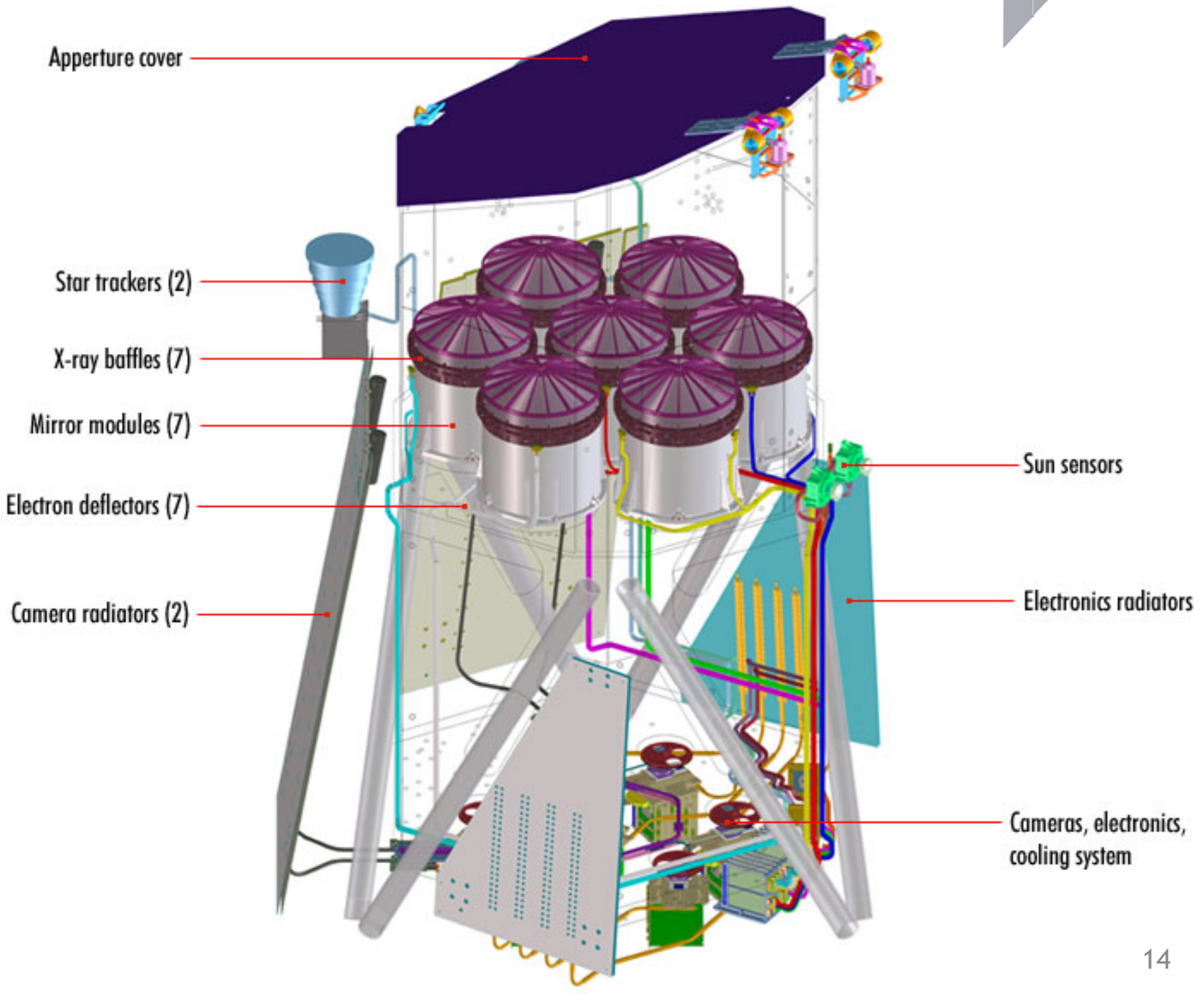
nch

rvatory

10^4 Galaxy Clusters

SMEX-proposal in the US was not selected

eROSITA telescope



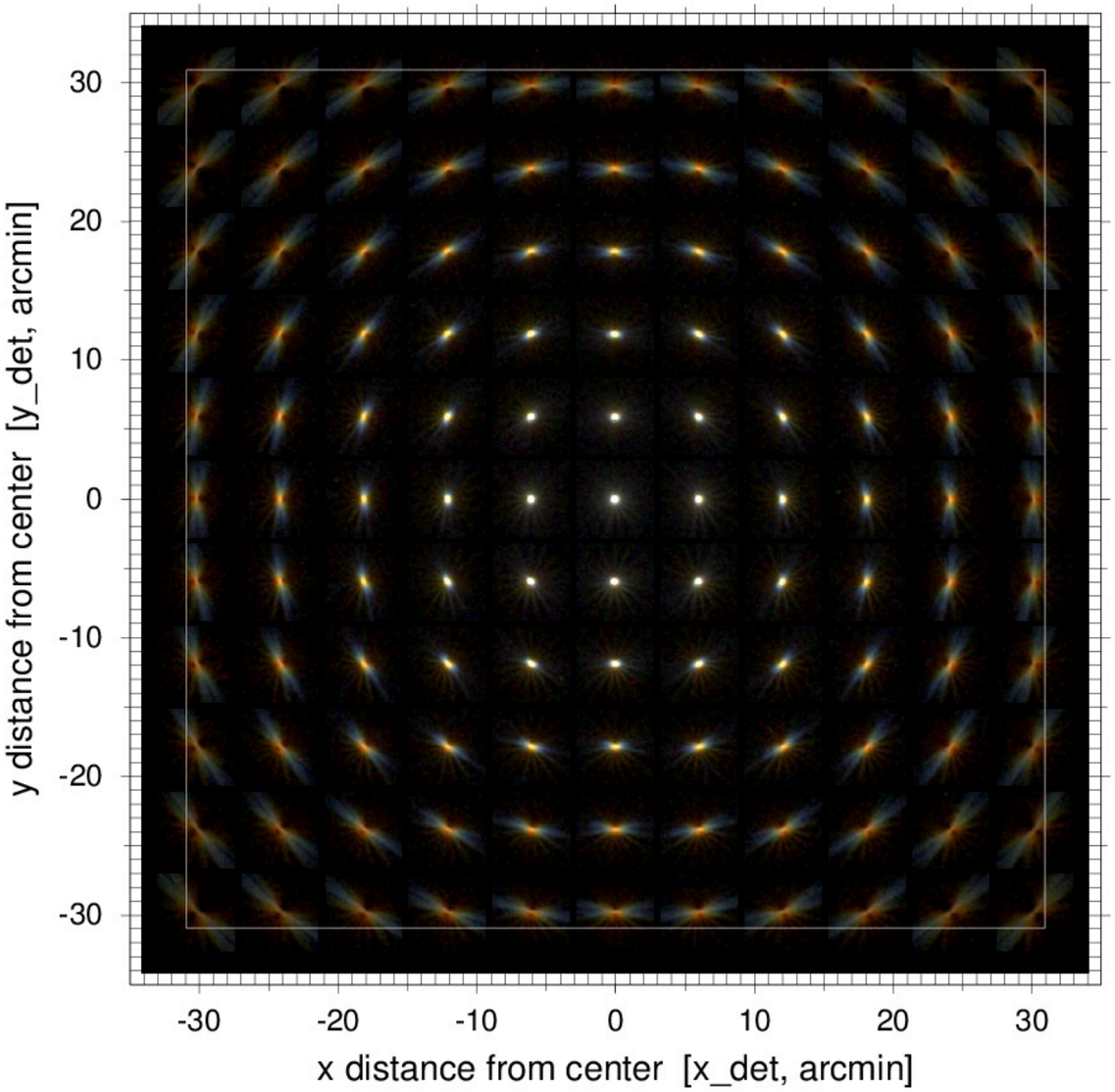
ART-XC (IKI)

Navigator
(NPO Lavochkin)

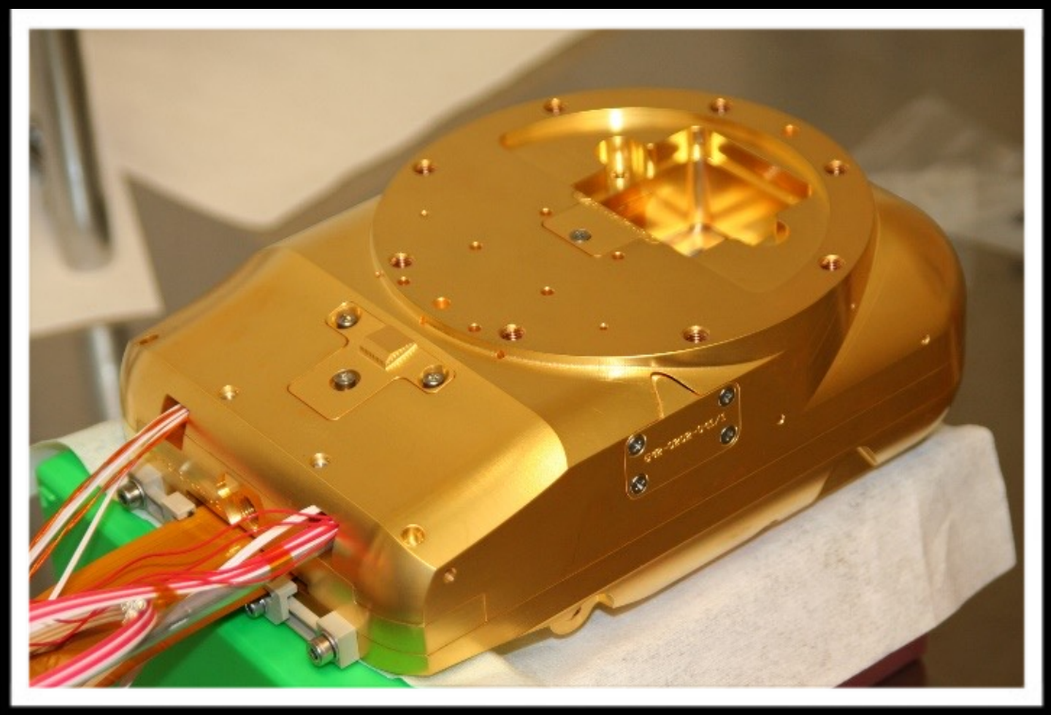
eROSITA (MPE)

Спектр-РГ

7 Mirrors + pnCCDs

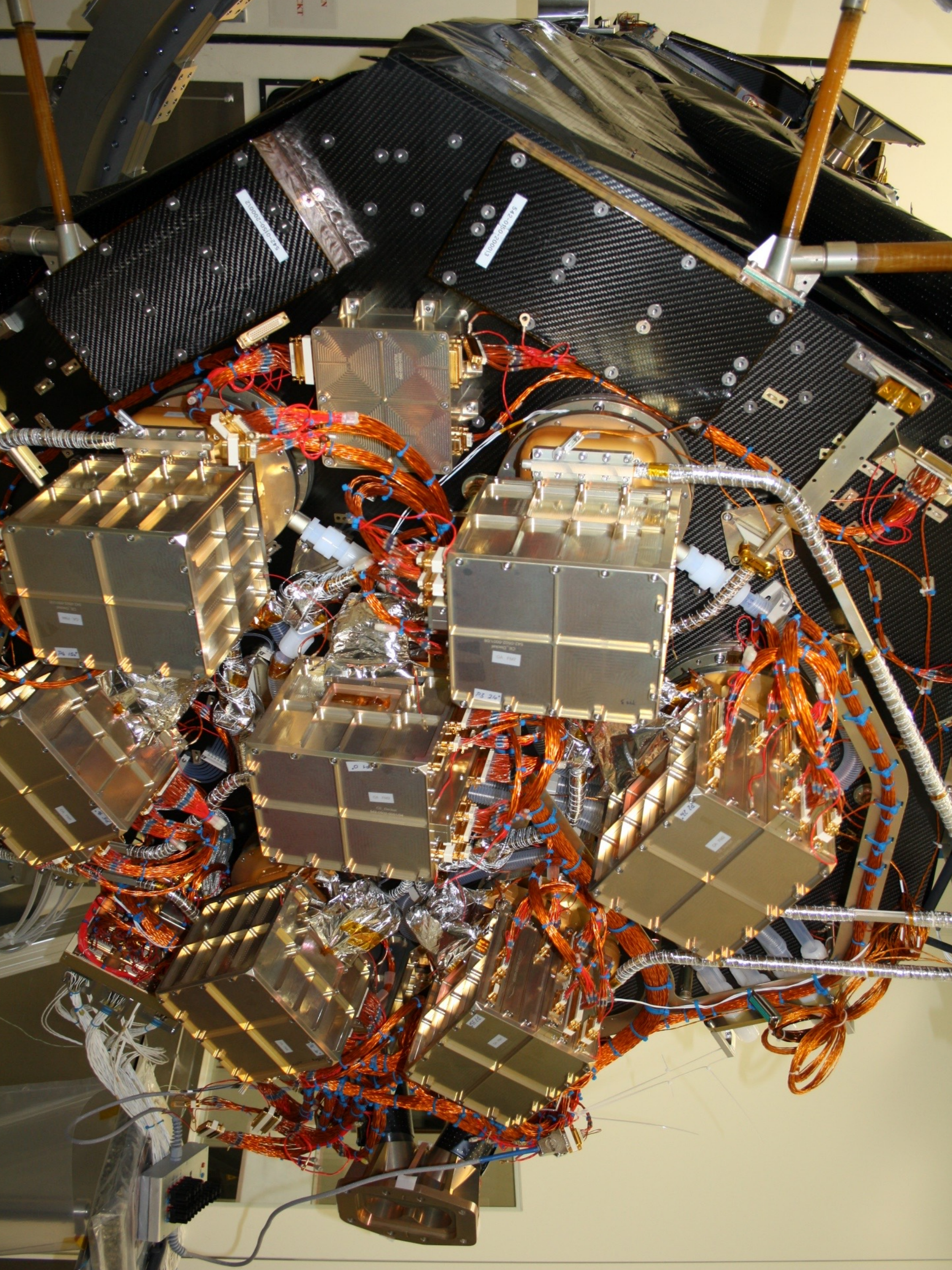


- Focal length: 1.6 m. **Field of view: 1 degree (diameter)**
- Half-Energy width **(HEW) ~18" (on-axis, point.); ~26" (FoV avg., survey)**
- Source location accuracy ~3-5"
- X-ray baffle (10μm precision alignment): 92% stray light reduction
- pnCCD with Framestore (no 'out of time' events), **no chip gaps**
- Extremely **good detector uniformity, little temperature dependence**
- **Spectral resolution** at all measured energies within specs (**~80eV @1.5keV**)



Camera shielded in 4 cm thick copper

Filter wheels with calibration sources



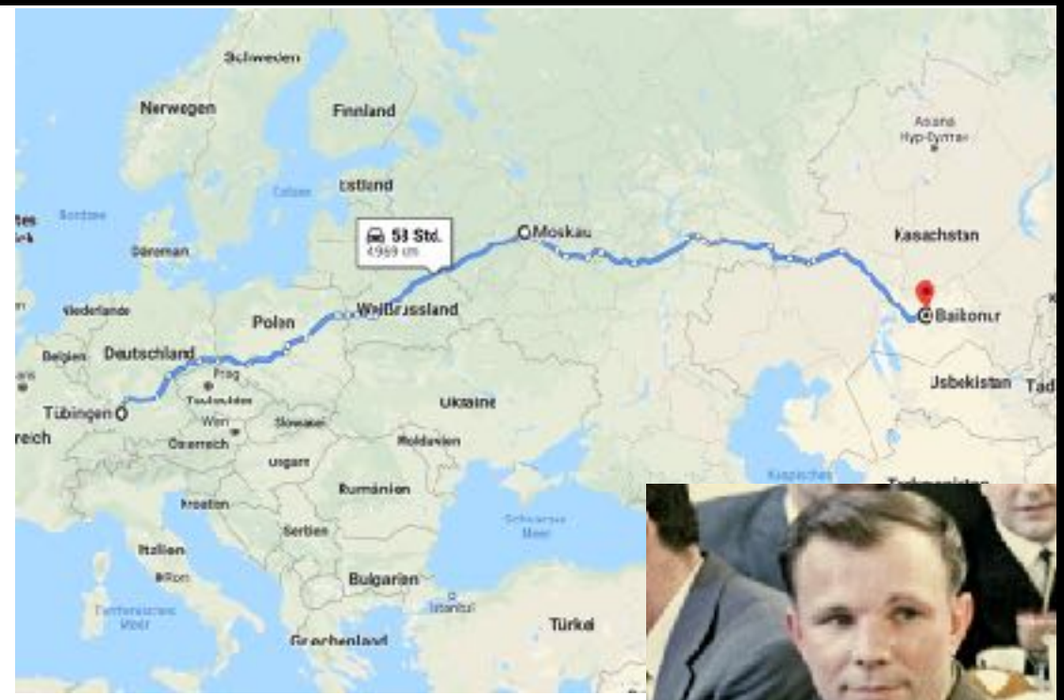

AirBridgeCargo
BOEING 747
25
M
Verbindung leben
AT449
FedEx
132-3V


13R
9R
14R
10R
STA 1200
8L
9L
HBSU 204955 0
22G1
MAX. GR. 30.480 KG 67.200 LB
TARE 2.150 KG 4.740 LB
NET 28.330 KG 62.460 LB
CU. CAP. 33.1 CUM. 1.170 CUFT.
8R 9R
STA 1300
9R 10R


РОСКОСМОС

Baikonur kosmodrom

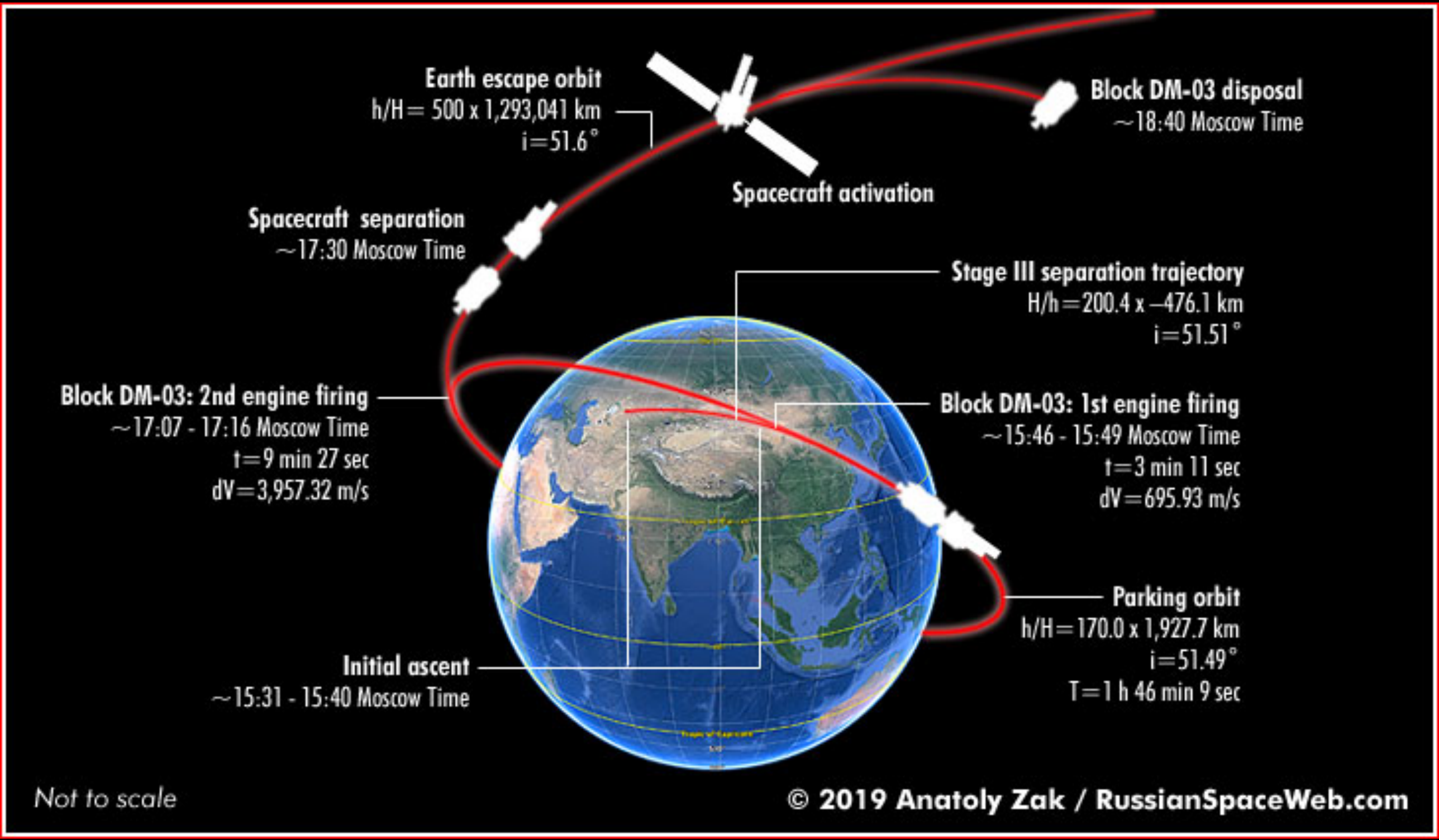
- First (1955) and largest rocket launch site in the world (kosmodrom) (into orbit, i.e. non-ballistic)
  - 15 launch sites for 9 rocket types
  - area of 6717 km2 (~3 Saarland)
  - close to 3000 launches in total
    - SRG was 10th this year
- Built mainly to test R-7 ICBM
- Developed to what it is:
  - **Sputnik** (1957, start of space era)
  - **Sputnik-2** (1957, first creature in space)
  - **Vostok-1** (1961, first man in space)
  - **Vostok-6** (1963, first woman in space)
  - **Voschod-2** (1965, first spacewalk)
  - Buran/Energija (1988, first autonomous flight/landing)
- Currently rented by Russia from Kazakhstan (115 Musd/year if you're interested)
- Still the main launch site in Russia

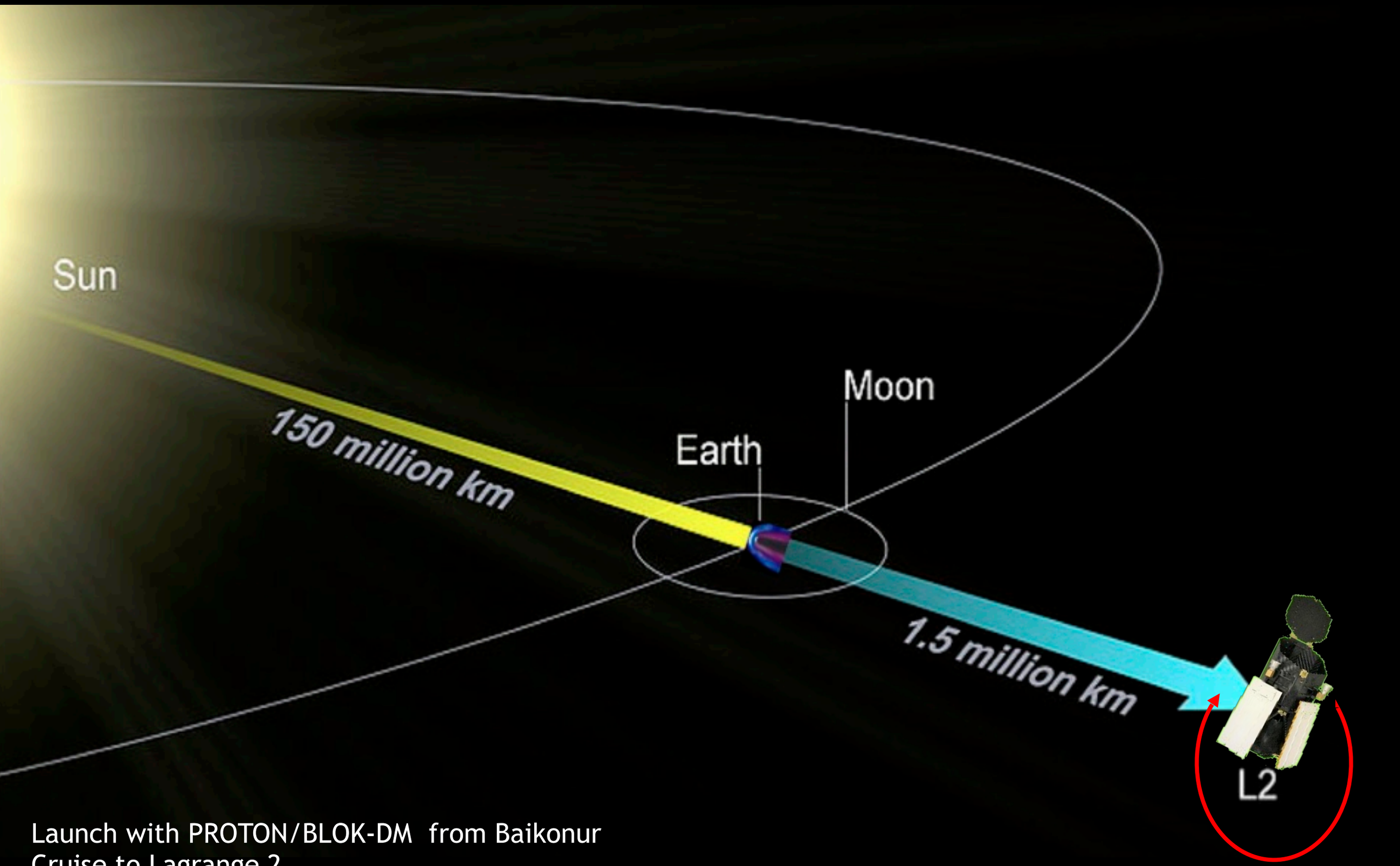


Launch on the 13th of July, 2019, 5:31 PM

credit Vadim Burwitz (MPE, handheld with Nikon coolpix P1000)

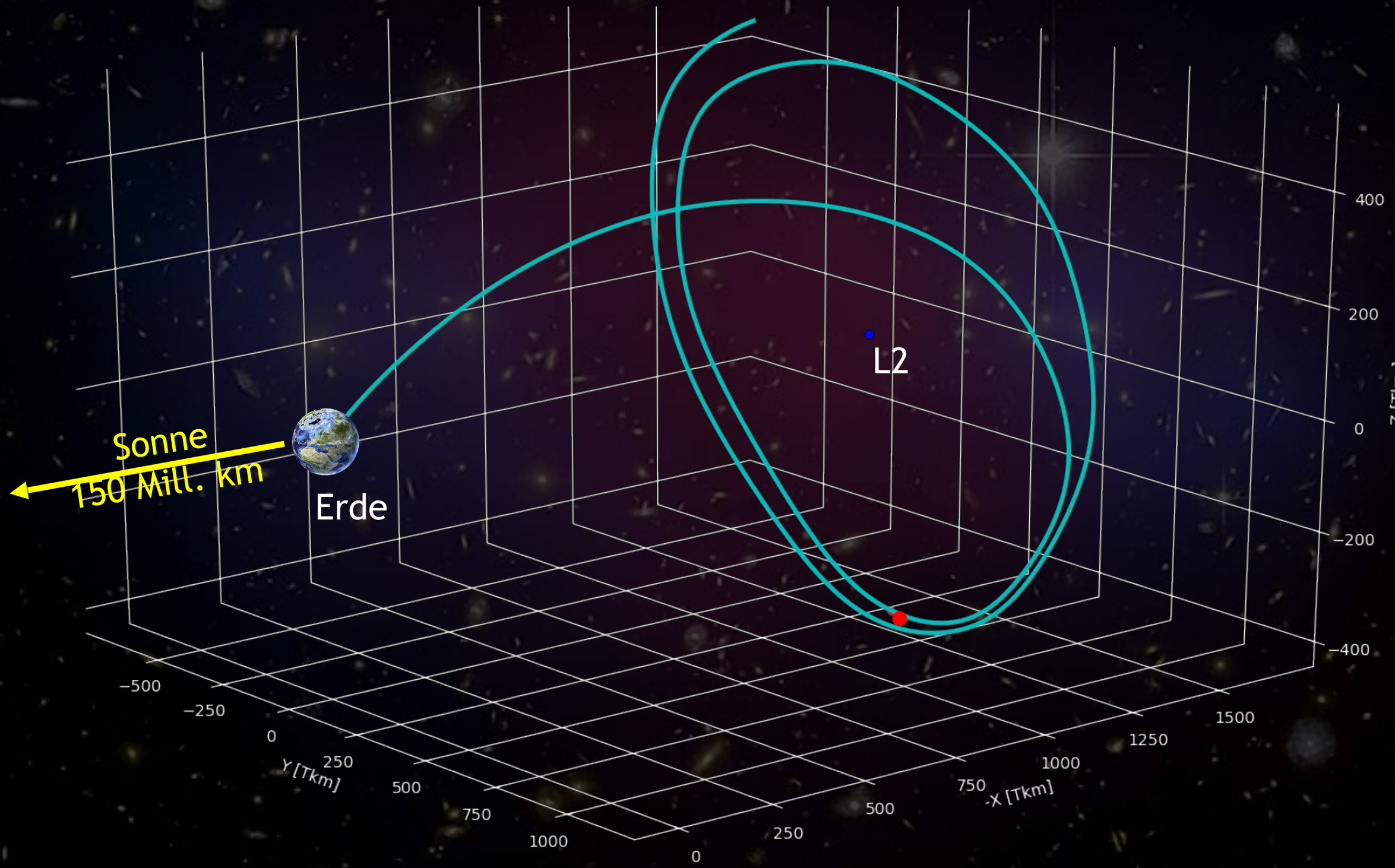
credit Alexander Ivanov (Jun 13 21:13-02:40 Moscow time with Maksutov 243/1200)


Earth escape orbit
h/H = 500 x 1,293,041 km
i=51.6°
Block DM-03 disposal
~18:40 Moscow Time
Spacecraft activation
Spacecraft separation
~17:30 Moscow Time
Stage III separation trajectory
H/h=200.4 x –476.1 km
i=51.51°
Block DM-03: 2nd engine firing
~17:07 - 17:16 Moscow Time
t=9 min 27 sec
dV=3,957.32 m/s
Block DM-03: 1st engine firing
~15:46 - 15:49 Moscow Time
t=3 min 11 sec
dV=695.93 m/s
Parking orbit
h/H=170.0 x 1,927.7 km
i=51.49°
T=1 h 46 min 9 sec
Initial ascent
~15:31 - 15:40 Moscow Time
Not to scale
© 2019 Anatoly Zak / RussianSpaceWeb.com



Launch with PROTON/BLOK-DM from Baikonur
Cruise to Lagrange 2
4 years survey, continuous rotation (~4hr)
3 years pointed observations

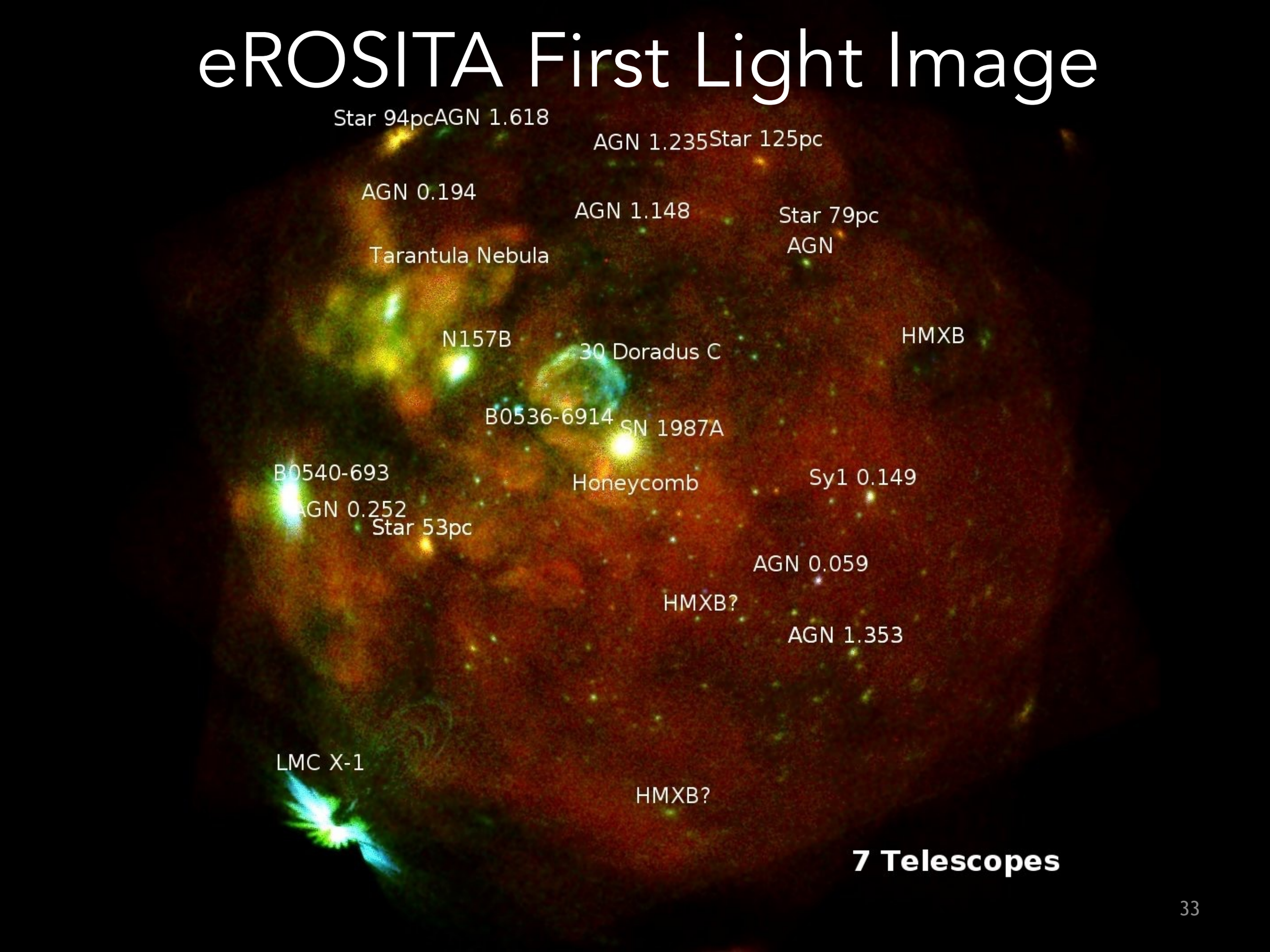
L2 Orbit


L2
Sonne
150 Mill. km
Erde
400
200
0
−200
−400
Z [Tkm]
−500
−250
0
250
500
750
1000
Y [Tkm]
0
250
500
750
1000
1250
1500
-X [Tkm]

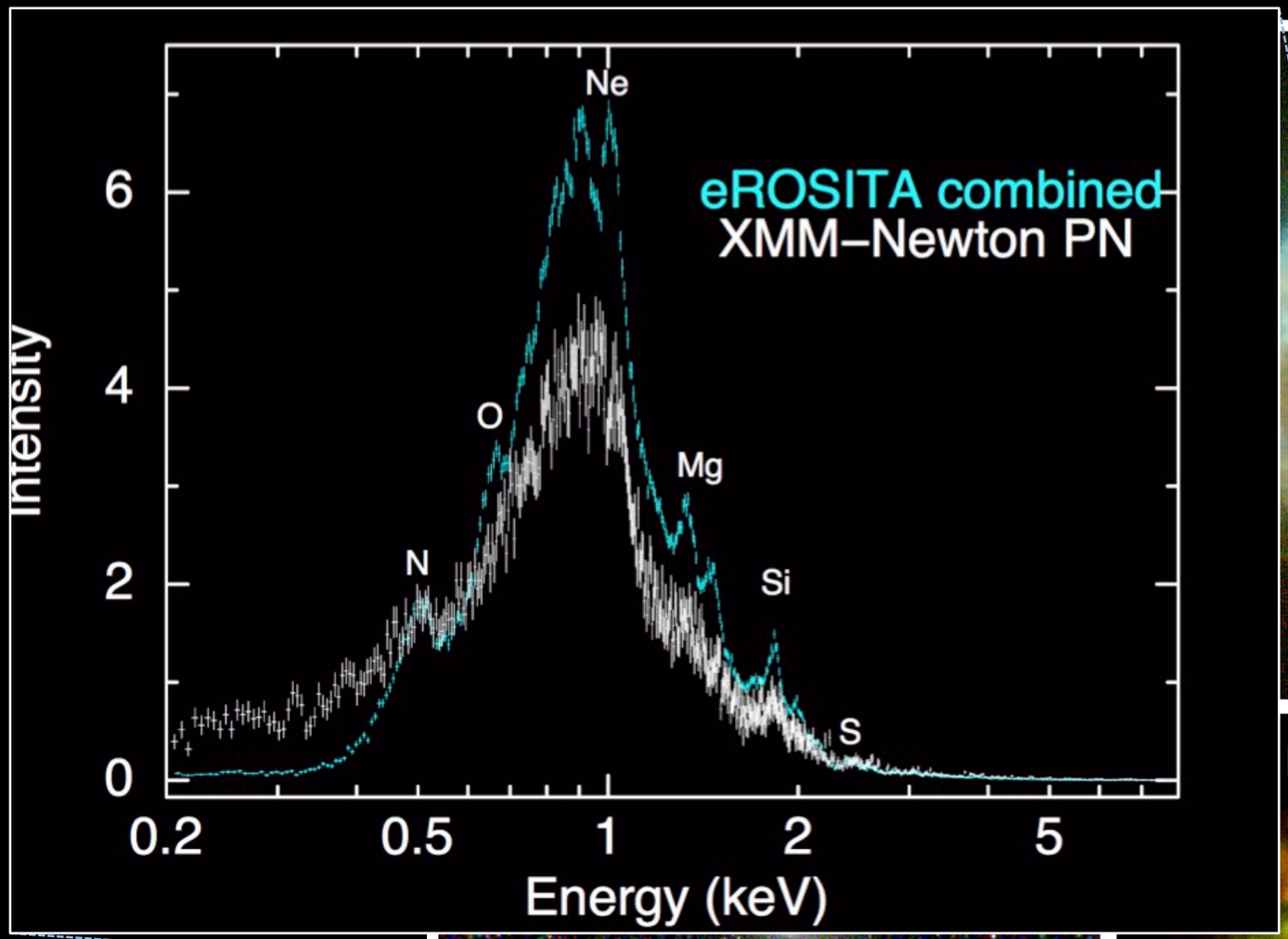
First Year of Operations

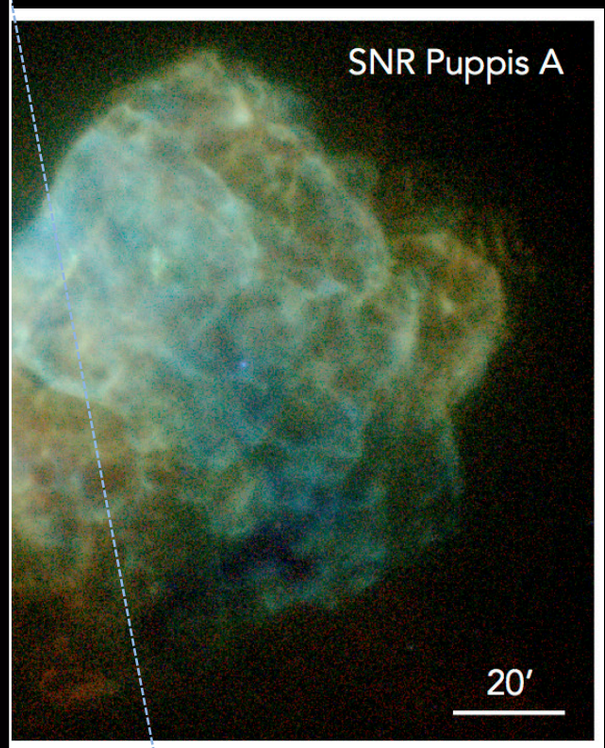
eROSITA First Light Image

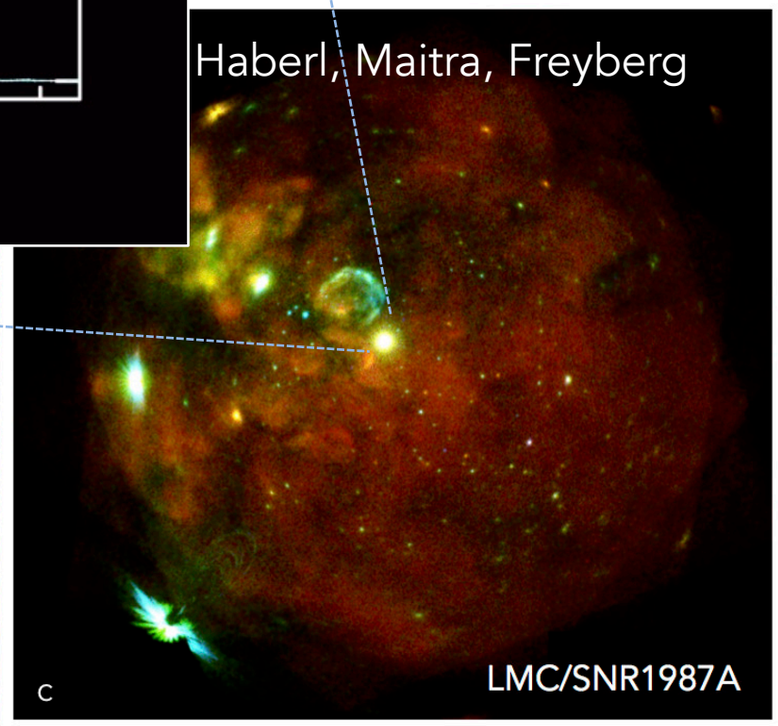
eROSITA First Light Image



Highlights from CalPV phase

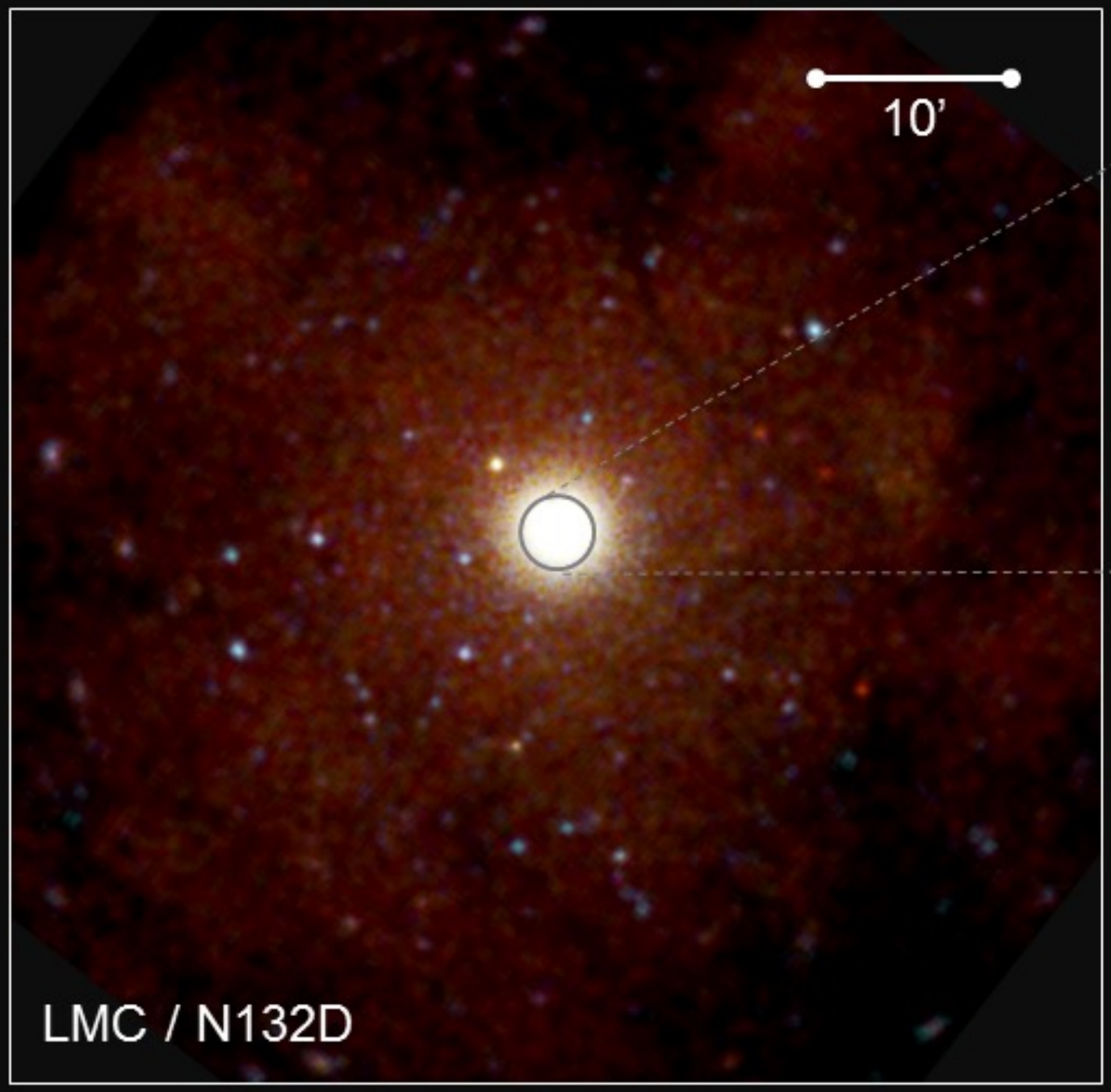




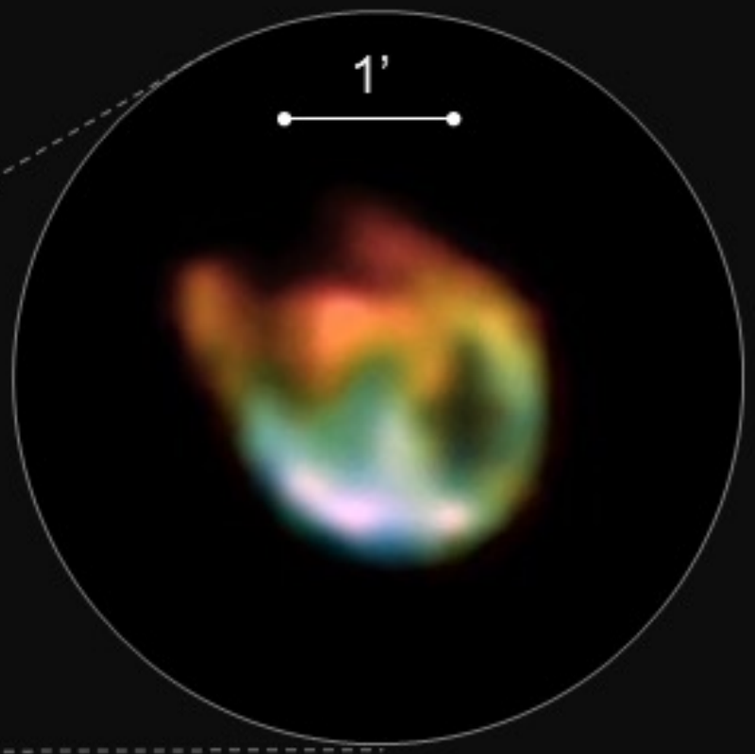


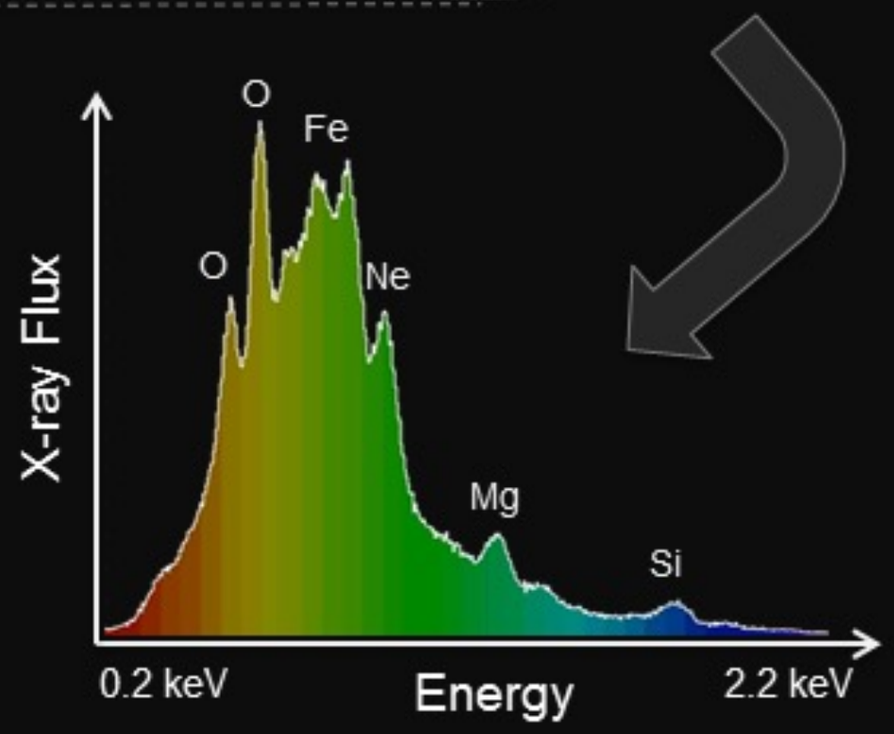
Merloni, Nandra, Predehl, Nat. Astr. (2020)

SRG / eROSITA 0.2 - 2.2 keV



MPE/IKI

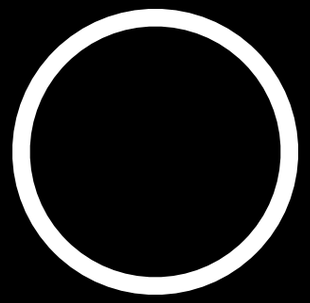




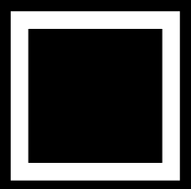
eROSITA's advantage

Moon diameter
30 arcmin

XMM-Newton
Field of view ~ 30 arcmin

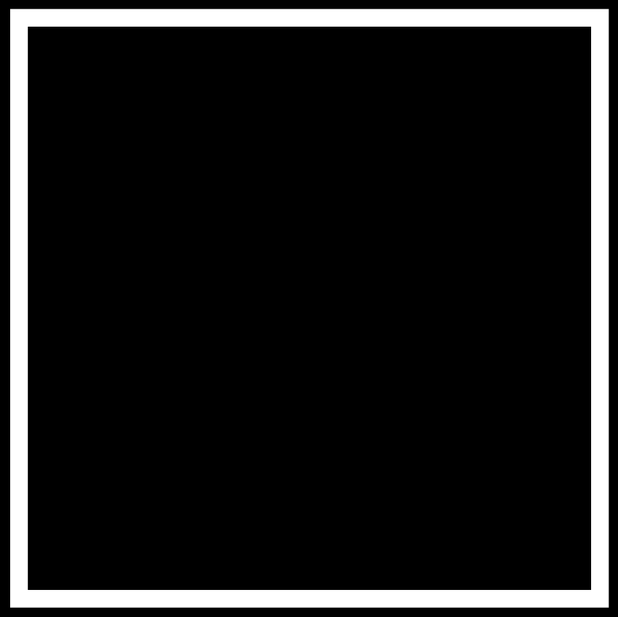


Chandra
Field of view ~ 17 arcmin



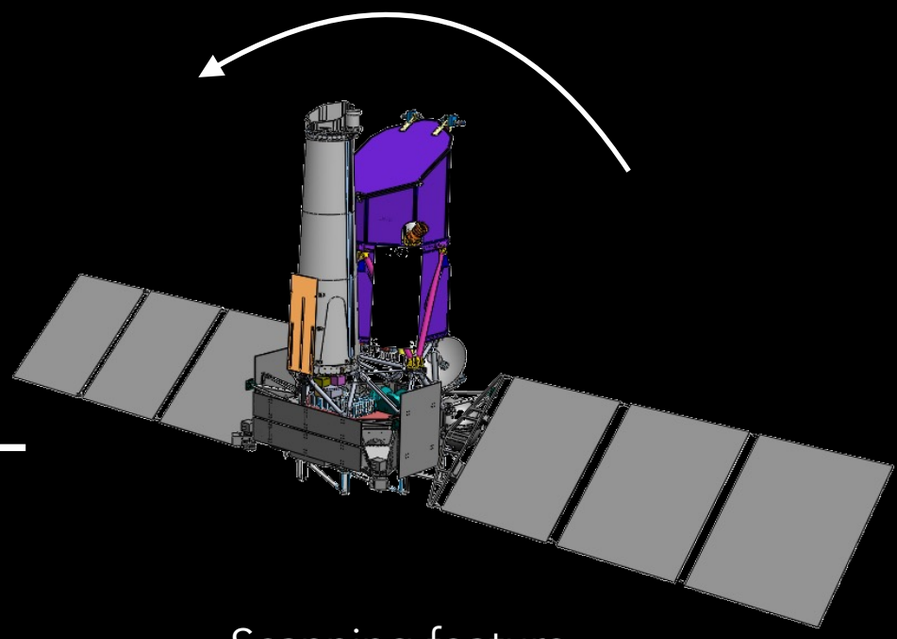
Typical observation duration: 50 ks
=> impossible to look at the full sky
(41,200 square degrees)

eROSITA
Field of view ~ 62 arcmin



+

4 h per rotation
half a year for complete sky coverage

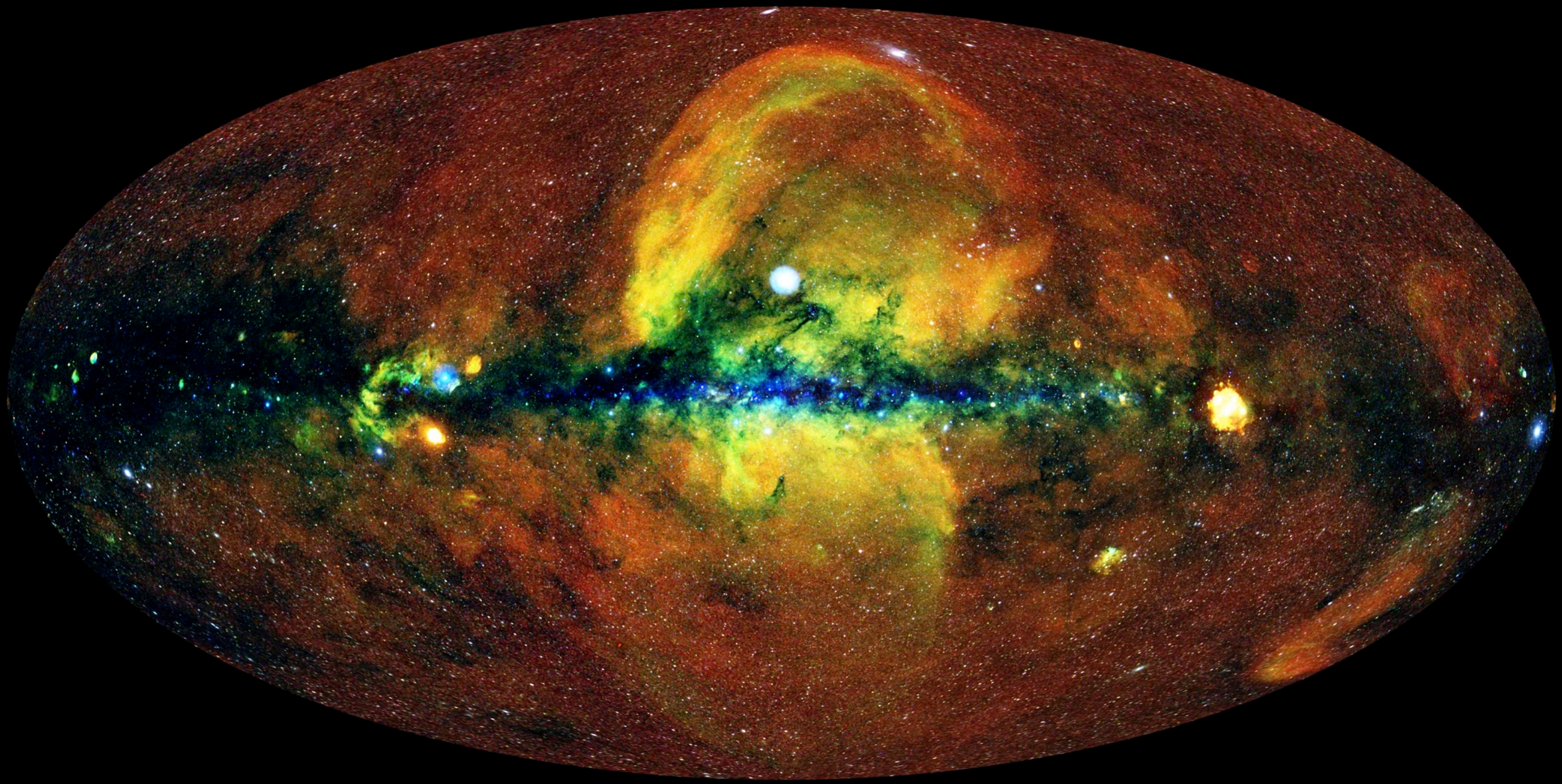


Scanning feature

eRASS:1, The first All-Sky Survey

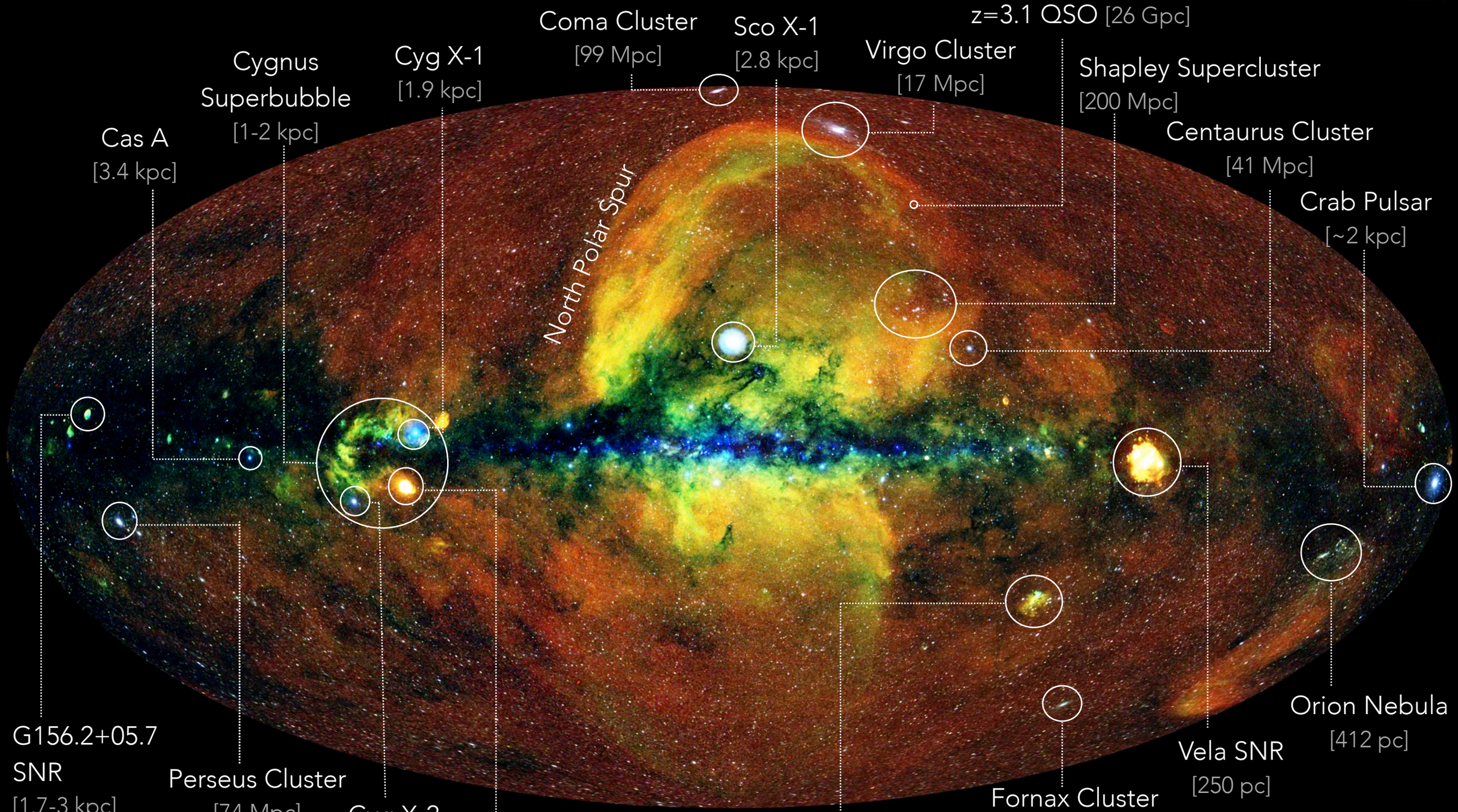
- Started on December 13, 2019, after a 2-months long Calibration and Performance Verification Program
- Completed on June 11, 2020
- Uniform exposure ~200s; up to 36ks at the Ecl. Poles
- Almost no background flares, flexible mission planning: no gaps in exposure
- ~400 Million 0.12-5keV calibrated photons
- About 1 Million sources detected (~80% AGN; 20% Stars)
  - Almost doubled the number of known X-ray sources
- ~20k clusters, up to z~1
- Numerous transients discovered; fine tuning vetting mechanisms, followup resources

SRG/eROSITA 0.3-2.3 keV - RGB Map



IKI J. Sanders, H. Brunner (MPE), E. Churazov, M. Gilfanov (IKI), and eSASS team MPE

Navigating the eROSITA X-ray sky

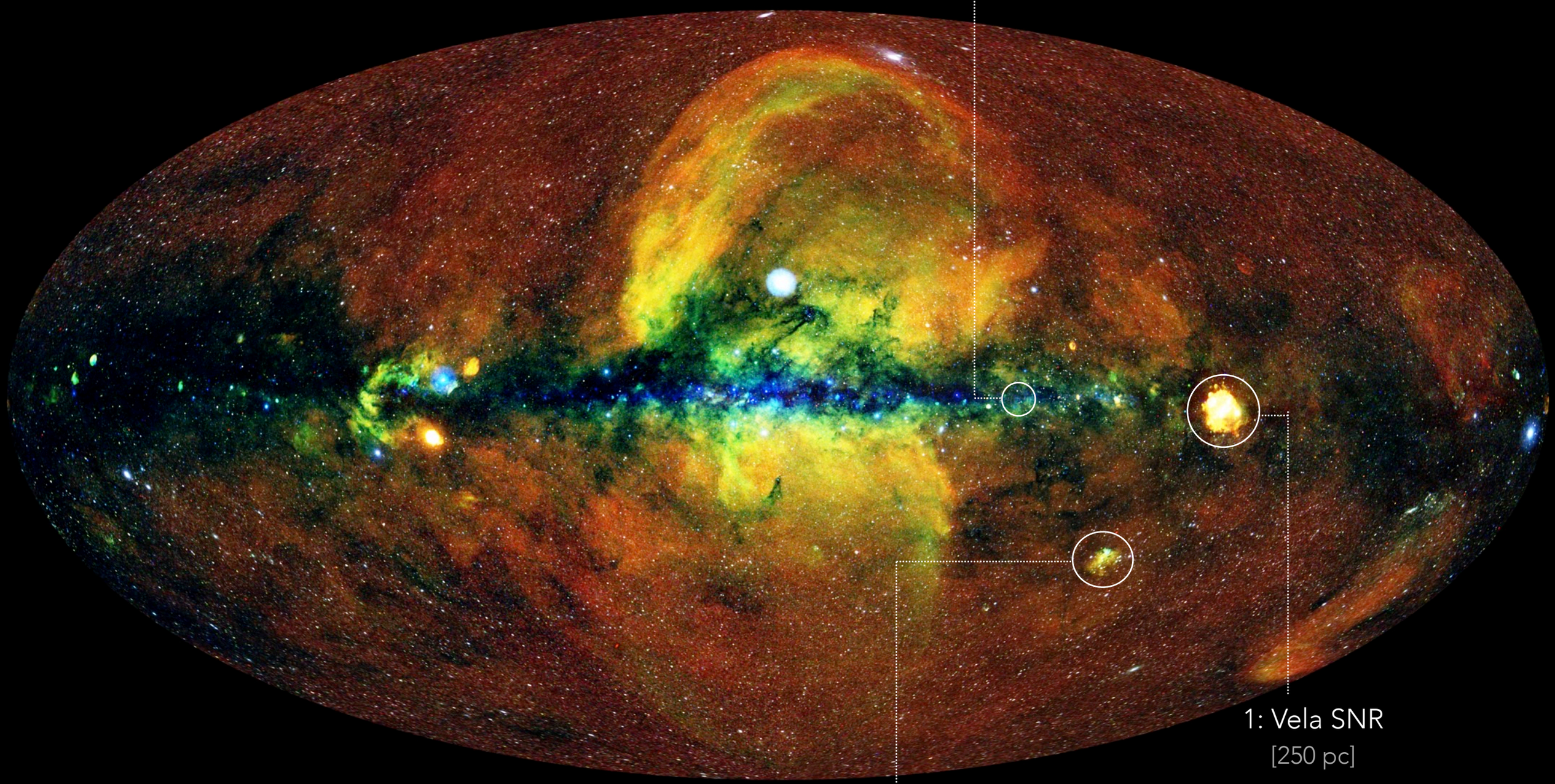


IKI

MPE

A few highlights from eRASS:1

eRASS:1 = eROSITA All-Sky Survey: first complete survey (there will be 8 in total)



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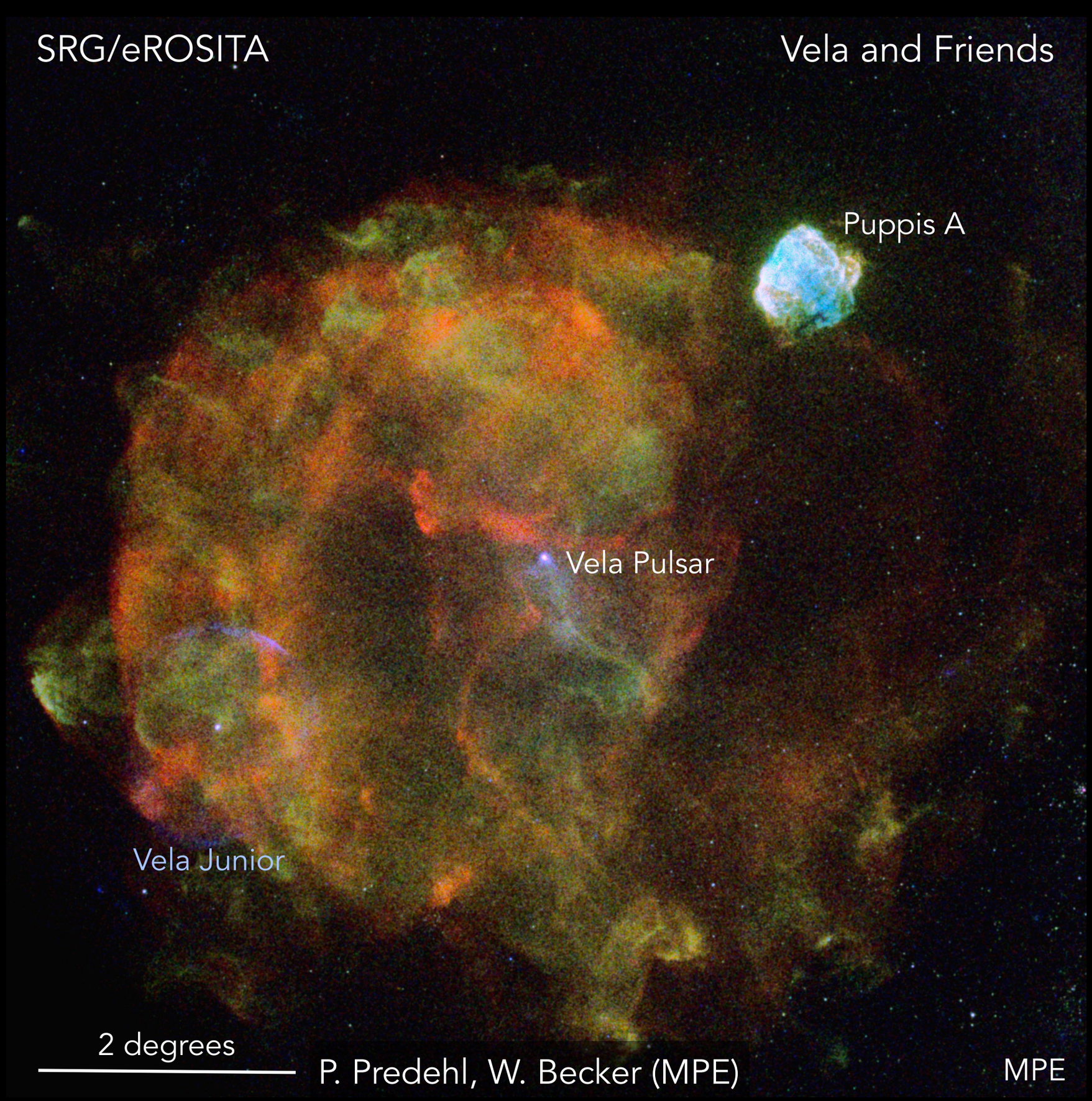
Vela and Friends

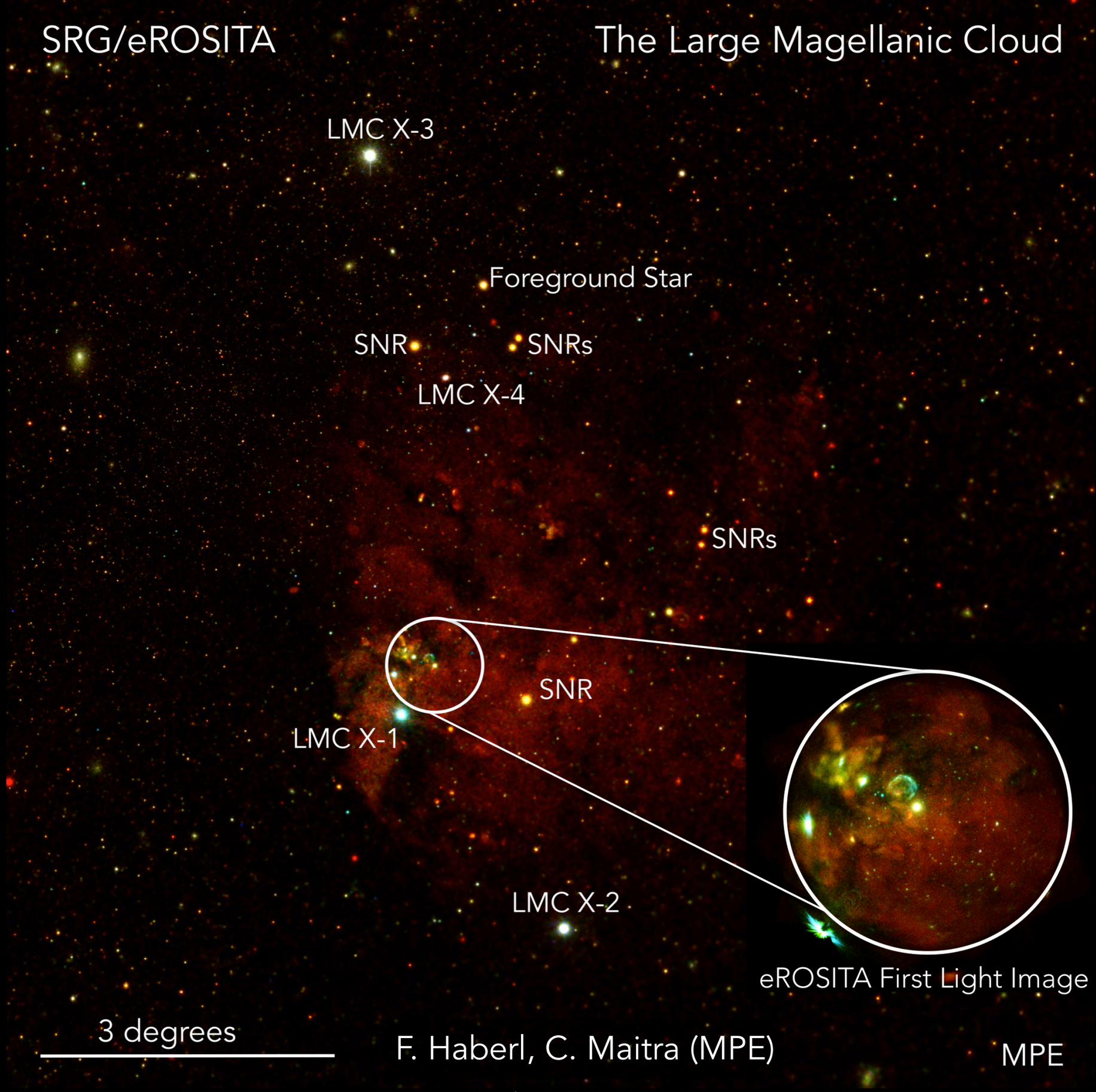


P. Predehl, W. Becker (MPE)

MPE

SRG/eROSITA

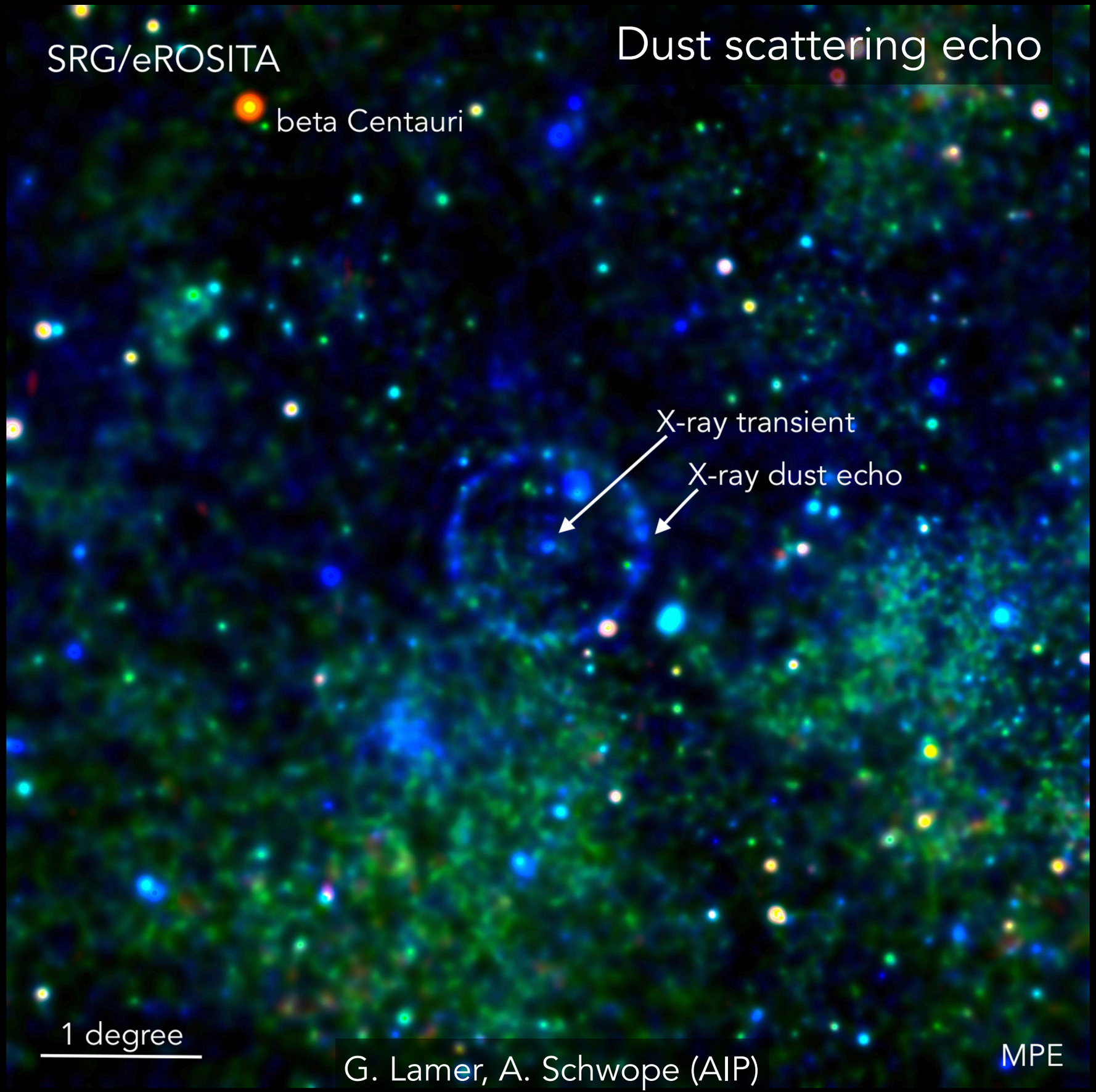
The Large Magellanic Cloud



F. Haberl, C. Maitra (MPE)

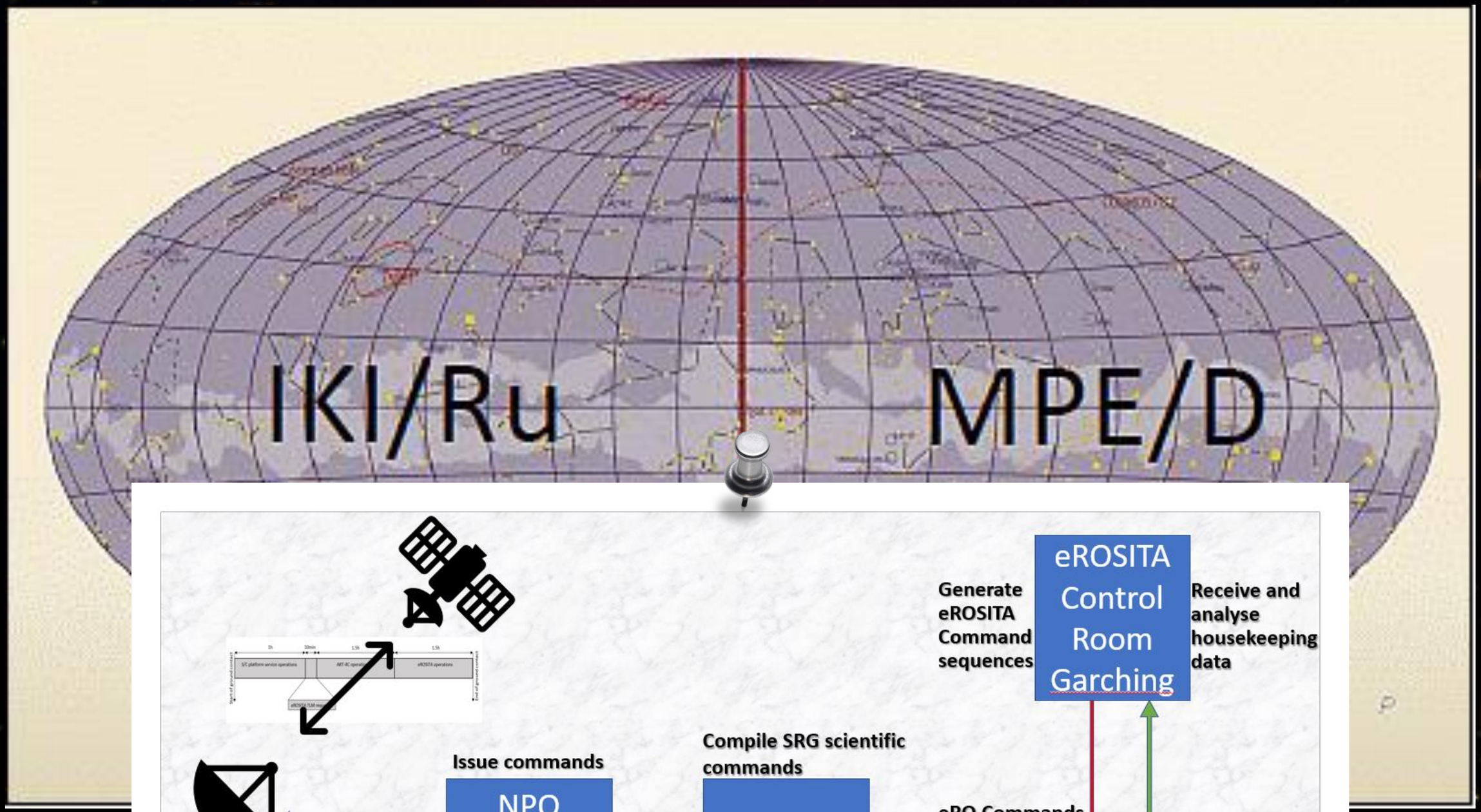
MPE

Dust scattering echo



Scan along the galactic plane

eROSITA data rights



eROSITA at a glance

Instrument

Size	1,9m Ø x 3.5m
Weight	810kg
Power	522W
Data volume	600MB/day
lifetime	> 7 years
Launcher	PROTON/BLOK-DM
Launch	13. Juli 2019
Mission	Orbit around L2

7 Camera Assemblies

pnCCD + Filterwheel + E-Box
3 x 3 cm ^{2}, pixelsize 75µm x 75µm
384 x 384 Pixel

Time Resolution	50 msec
Energy Resolution (1keV)	~ 70eV
Quantum Efficiency (1keV)	~ 95%

7 Mirror Assemblies

Wolter-I + X-ray Baffle + Electr. Div.

Diameter of outer shell	358mm
Number of shells	54
focal length	1600mm
PSF/HEW on axis (1.5keV)	16 arcsec
HEW average FoV	26 arcsec
Effective Area (1.5keV)	350 cm^2
Field of View	1°

Performance

Energy Range	0.2-12keV
Point Source Sensitivity	1.2E-14
P.S. Sensitivity at poles	2.9E-15
Extended Source Sens	3.4E-14
ES. Sensitivity at poles	1.0E-14

eROSITA_DE

12 working Groups
135 Members
+ External Collaborators

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Thank you