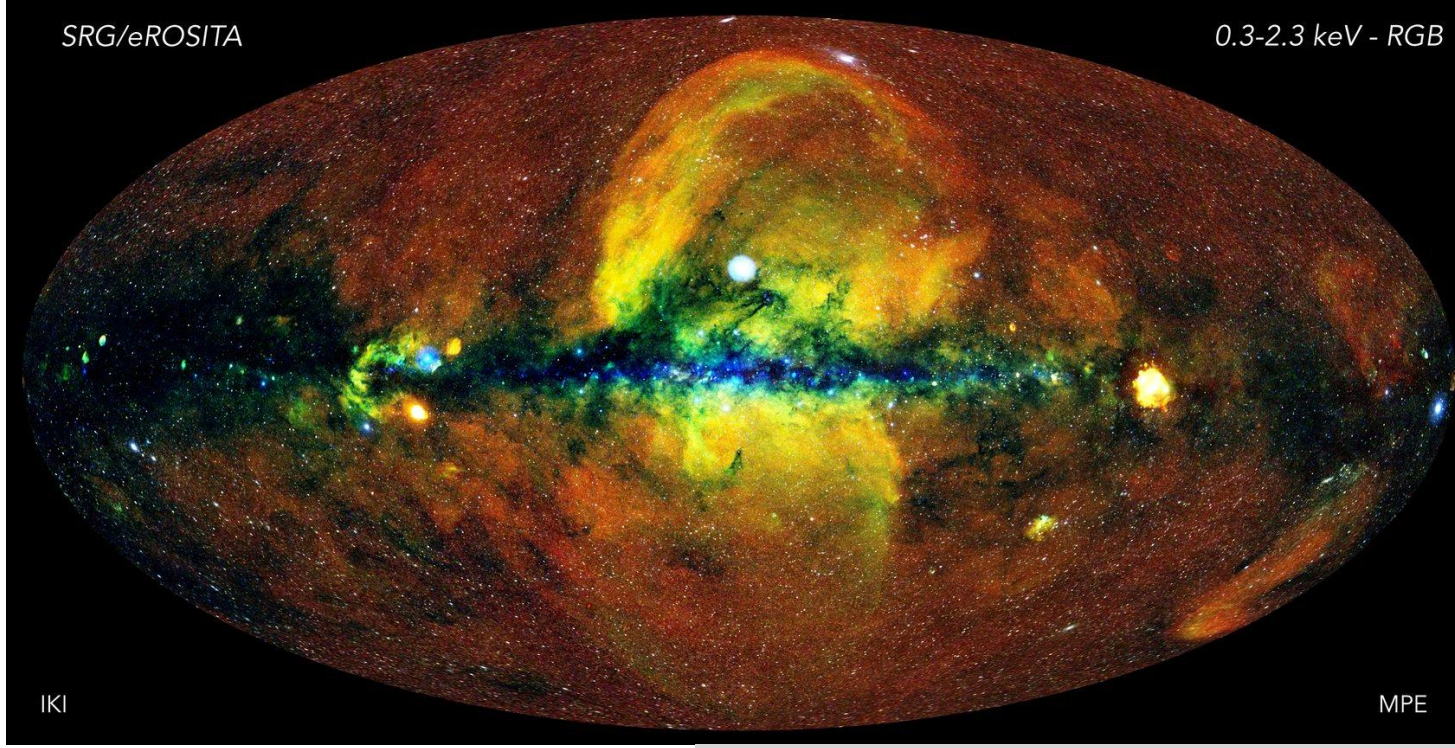
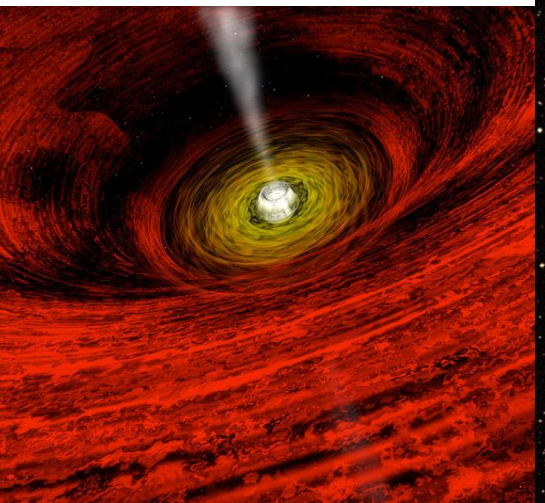
Copernicus 550
Meeting
Torun, Poland



February 21, 2023

Map of the entire sky in X-rays

31 months of the work in space

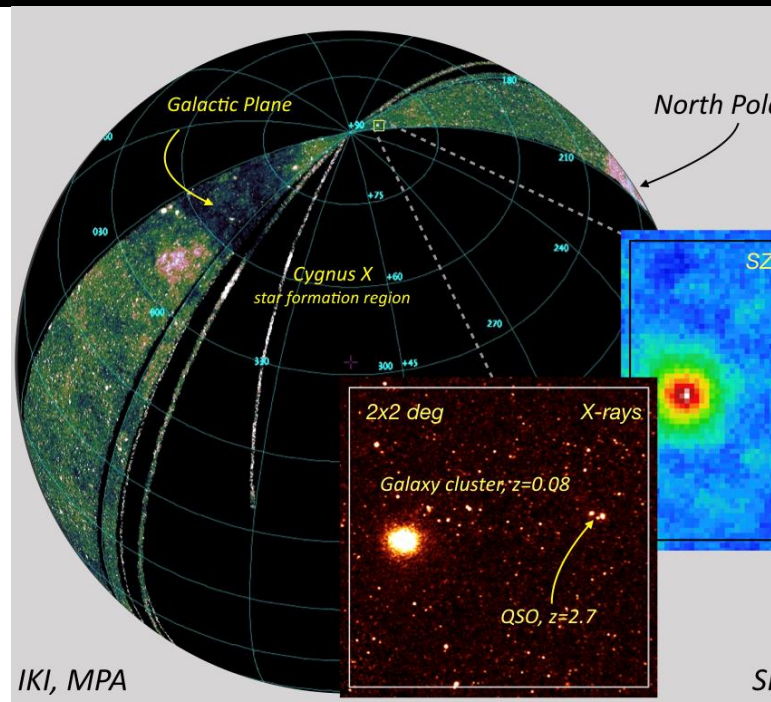


Rashid Sunyaev

Max-Planck Institute
for Astrophysics

Institute for Advances Study,
Princeton

Space Research Institute,
Moscow



Spectrum-RG (SRG, 2700 kg) Orbital Observatory

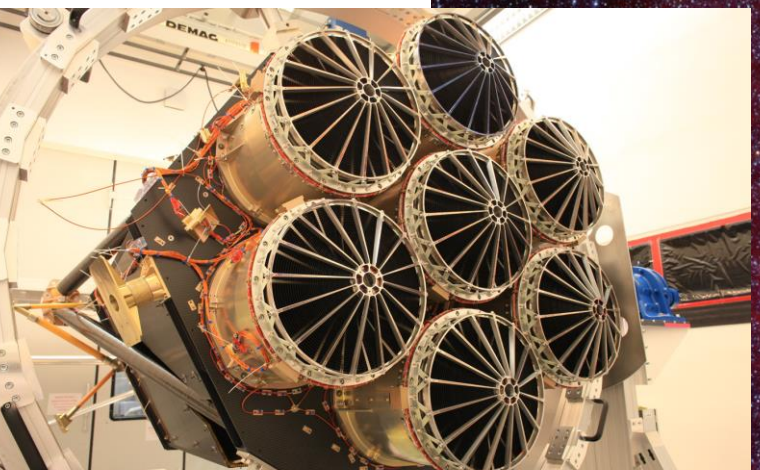
Located near L2 Point of the Sun-Earth system at the distance 1.5 Mln km from the Earth not very far from JWST (NASA) and Gaia (ESA)

ART-XC hard X-Ray Telescope (350 kg), IKI (Moscow), All-Russia Nuclear Center (Sarov) and Marshall Space Flight Center (NASA; X-Ray grazing incidence mirrors) 4 – 30 KeV

4 – 30 KeV

eRosita, 808 kg
1.9 m * 3.5 m

NAVIGATOR platform



eRosita (MPE) has seven parallel grazing incidence mirror systems and seven X-Ray CCDs. Field of view is 1 degree, angular resolution 25”

0.3 – 9 KeV

Pixel - 9.6” * 9.6”

Lavochkin industry (near Moscow)
Launch 13.07.2019

Projection of the SRG trajectory onto the ecliptic plane

July 13, 2019
Proton launch

Baykonur,
Kazachstan

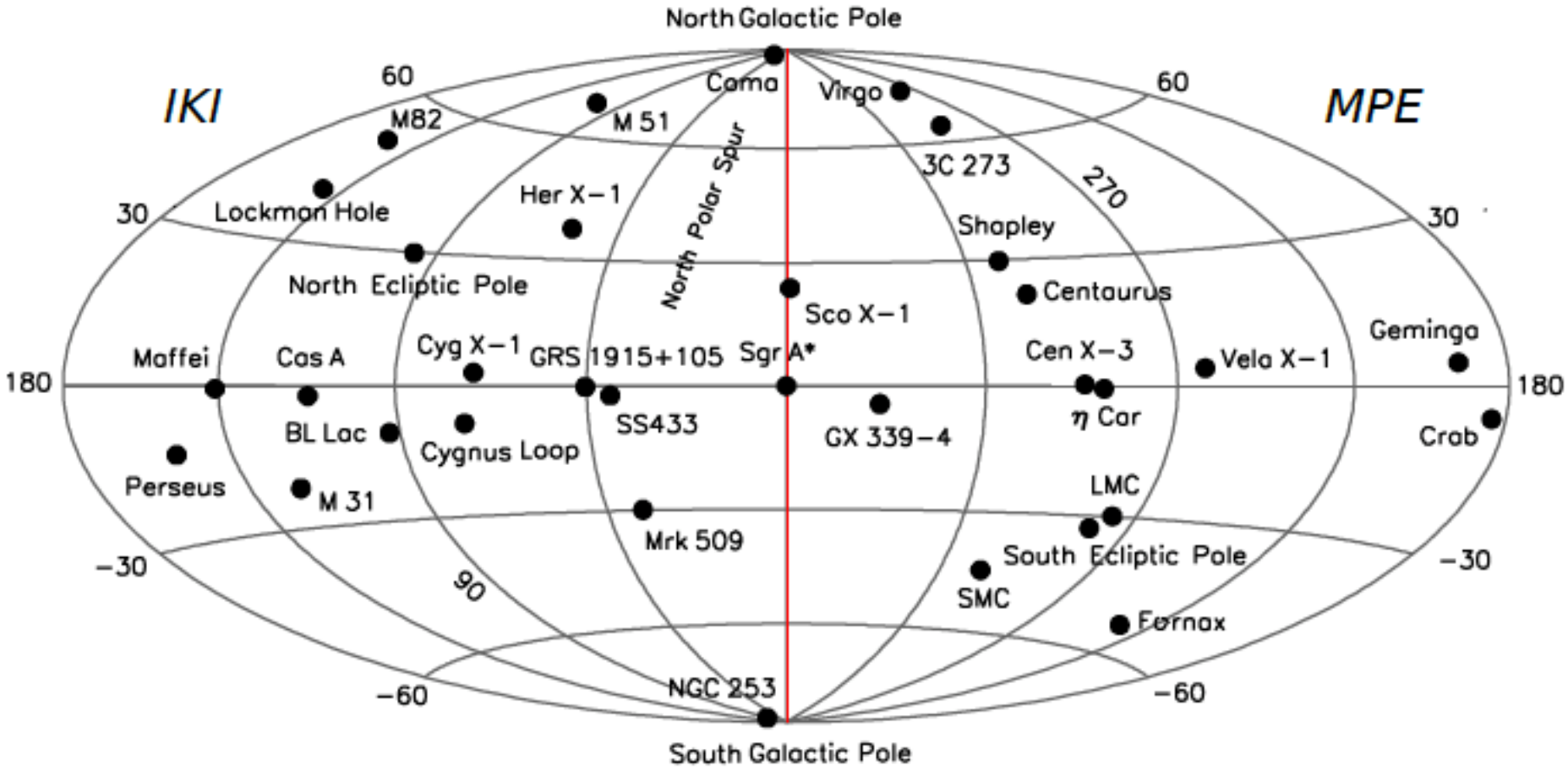
One revolution around L2 (and full sky map)
every half a year.

During 100 day long flight to the Lagrange point L2
there were adjustments, calibrations and
long observation of interesting areas and
sources in the framework of "Perfomance Verification"

2007: ROSKOSMOS and DLR (German Air and Space Agency) made the statement and included it into the Memorandum of Understanding:

for the data processing and publications of SRG/eRosita results on one half of the sky will be responsible Russian scientists. German scientists will be responsible for results from another hemisphere.

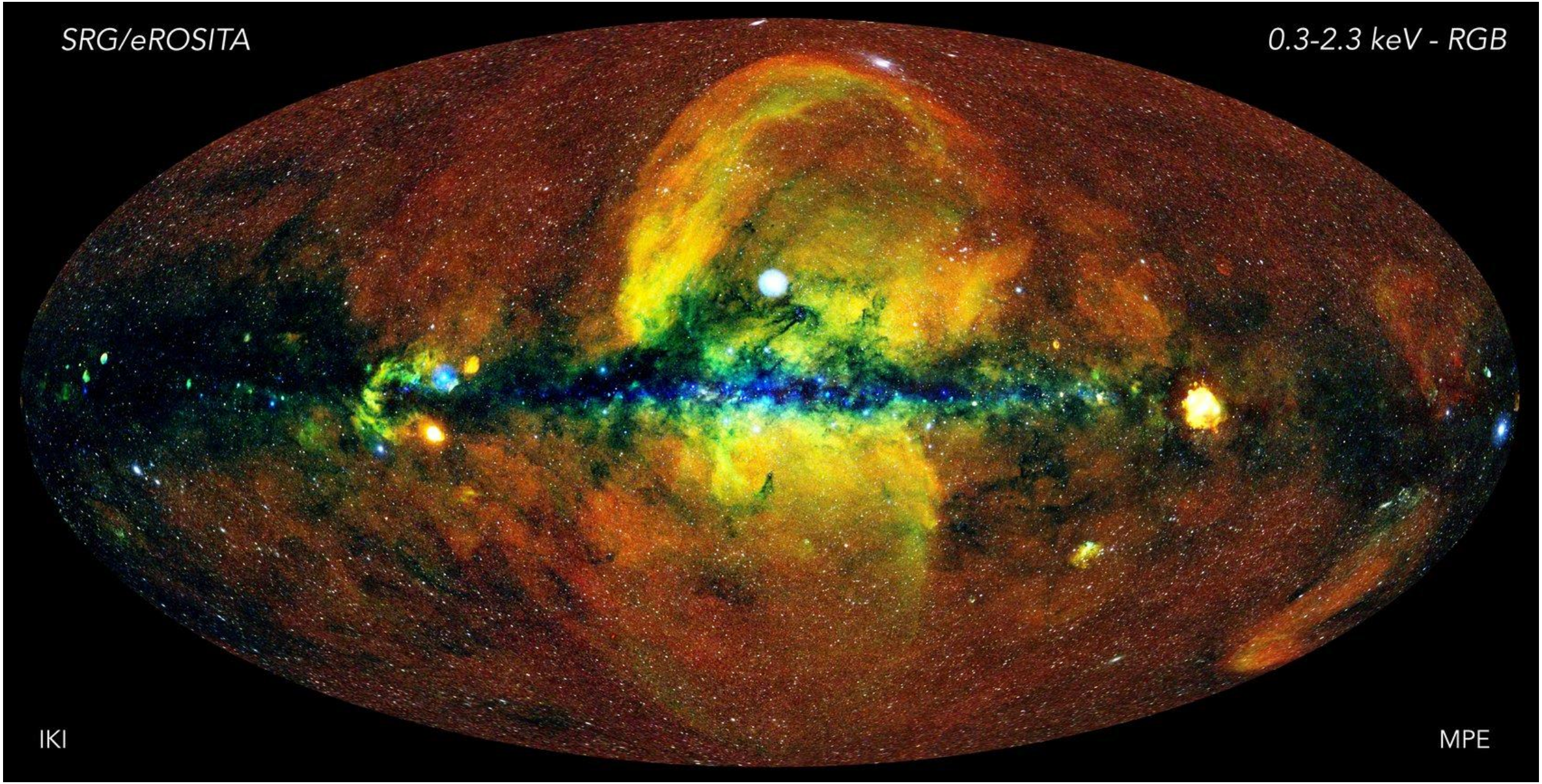
Galactic coordinates



IKI – Space Research Institute of the Russian Academy of Sciences

MPE – Max-Planck Institute fuer Extraterrestrische Physik

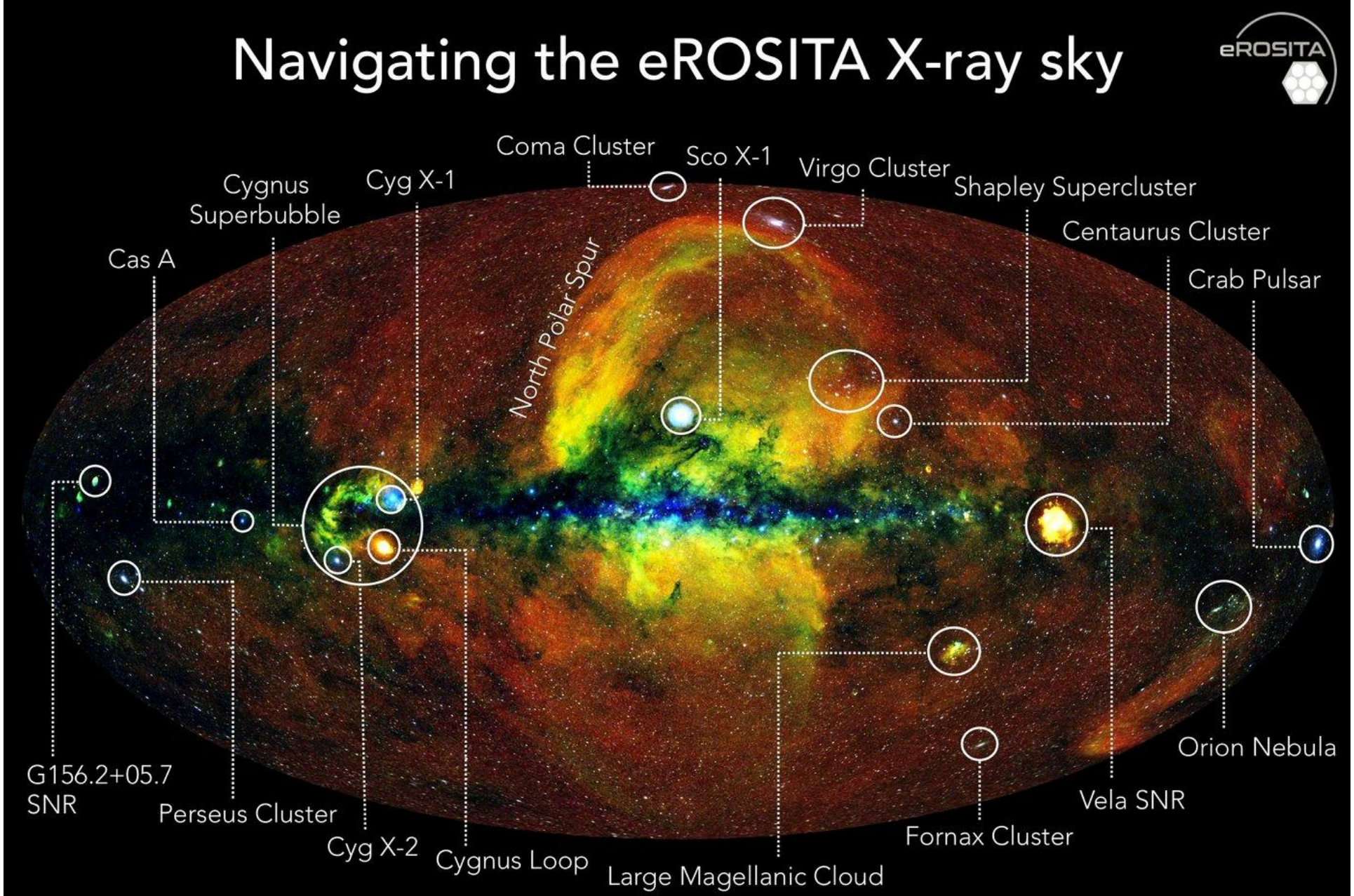
X-Ray Map of the entire Sky



Churazov, Gilfanov

Brunner, Sanders

Navigating the eROSITA X-ray sky



IKI

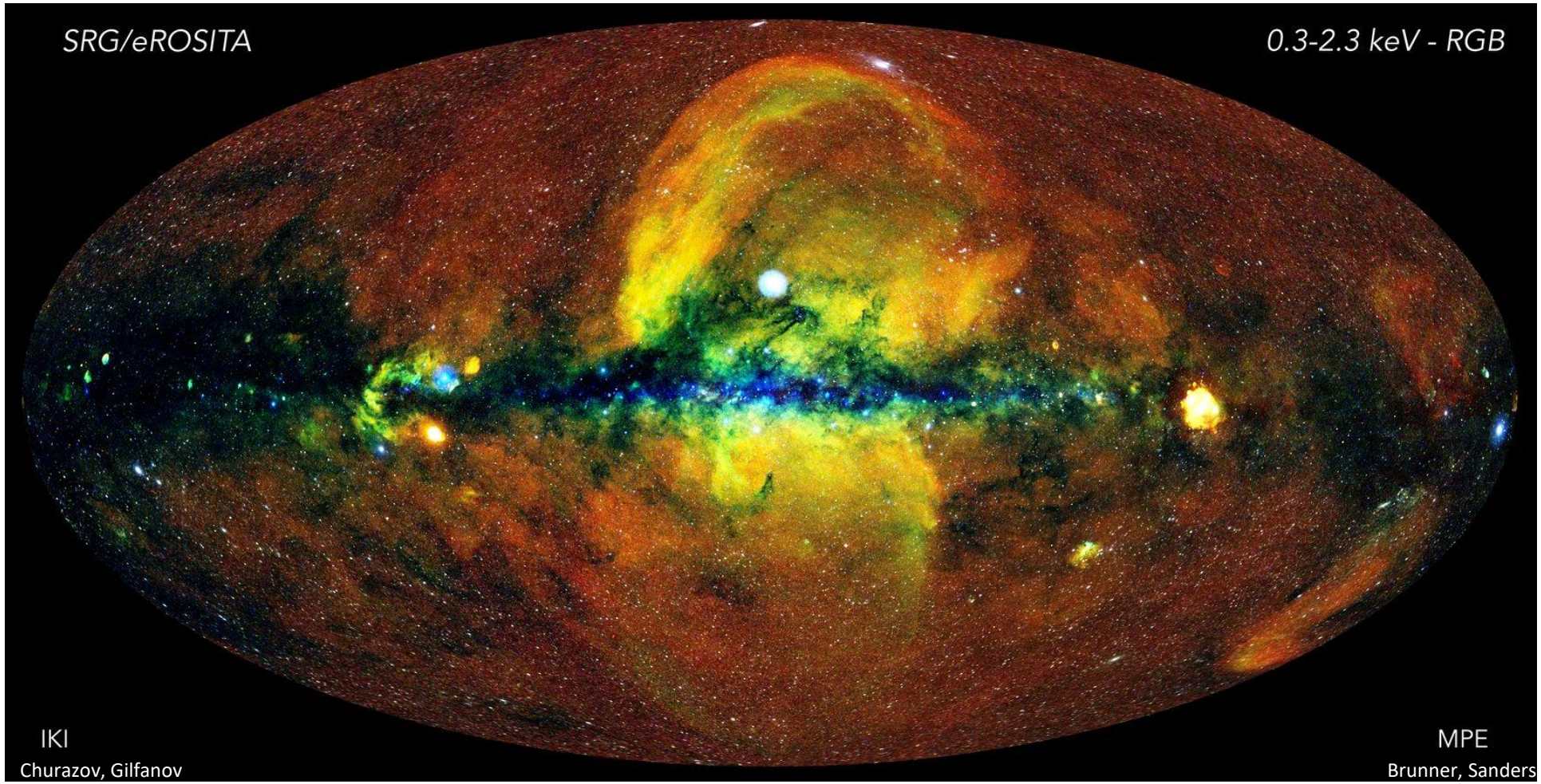
SRG/eROSITA 0.3-2.3 keV - RGB Map

MPE

Churazov, Gilfanov, Sunyaev

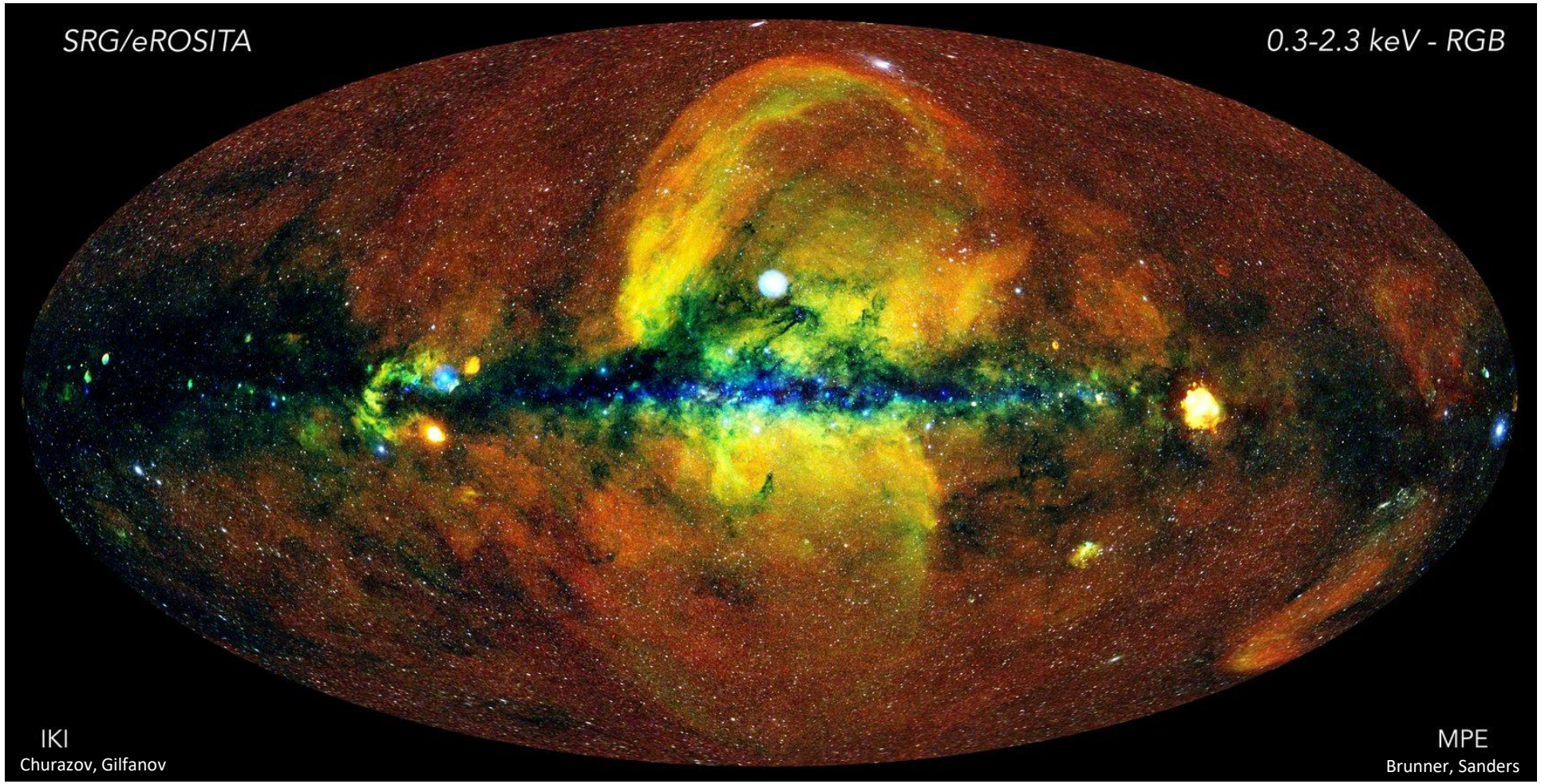
Brunner, Merloni, Sanders

First all-sky map of Rosita: **Million of X-Ray sources, Milky Way and traces of huge explosions at the Center of our Galaxy**



This is a three colour RGB map. All **400 millions of photons** with energies from 300 eV up to 2.3 KeV detected during half a year of continuous scanning are presented on this map. Red colour corresponds to photons with energies 0.3–0.6 KeV, green -- 0.6–1 KeV and blue – to 1–2.3 KeV. (Today after **26 months** of scanning the sky we have **more than one and a half billion of X-Ray photons**).

The first SRG all-sky survey allowed to construct a map containing almost 8 times more X-Ray sources than the former world-best map of the ROSAT satellite, obtained in 1990.

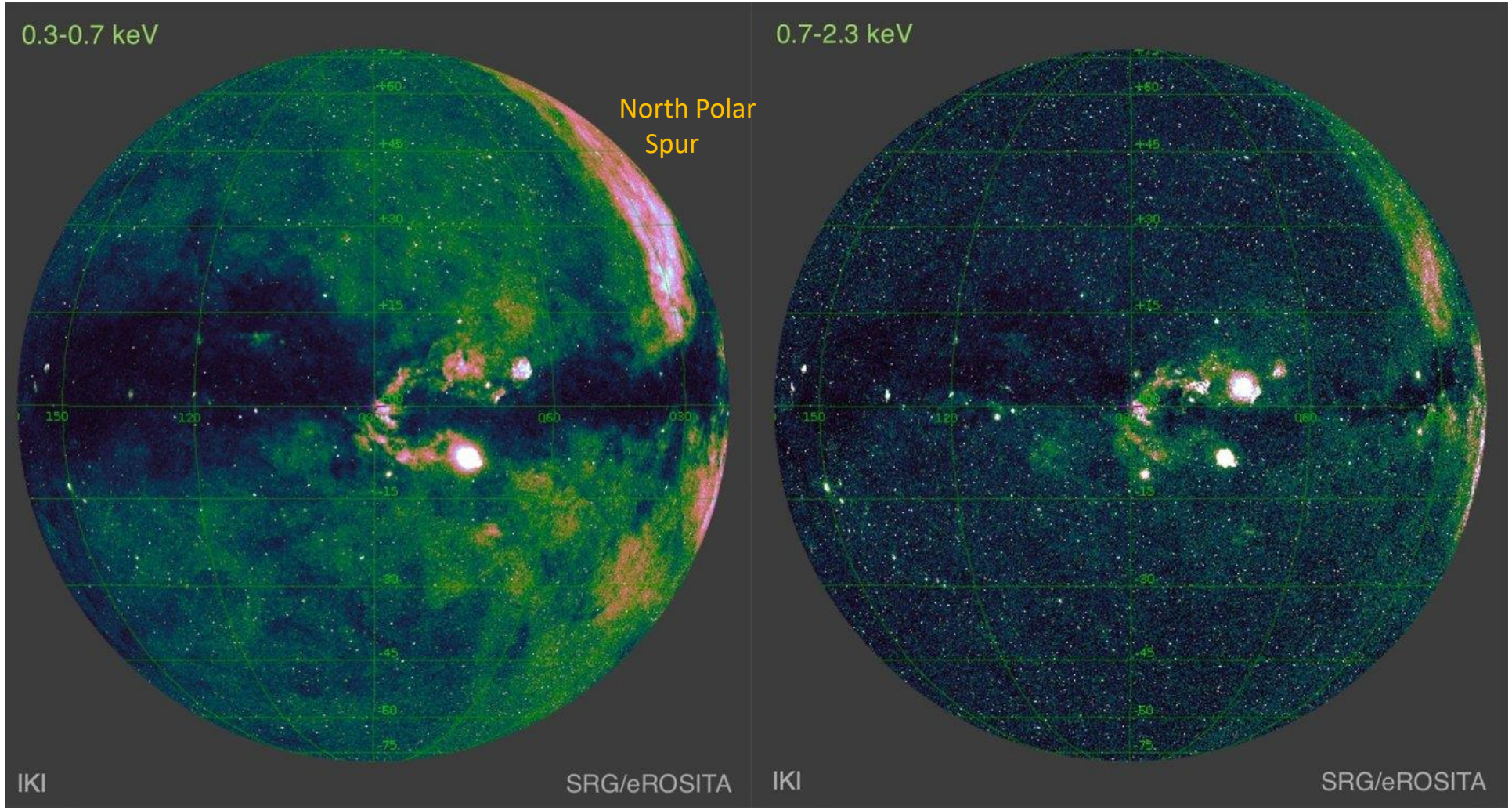


Three quarters of a Million objects on this map are distant quasars and active galactic nuclei powered by accretion of matter onto supermassive black holes residing in their centers. They are far beyond the Milky Way at distances of hundreds of millions and billions of light years from us. We see also 20 000 extended objects (mainly clusters and reach groups of galaxies with hot gas) and more than 200 000 galactic stars with active coronae. ***400 Millions photons***

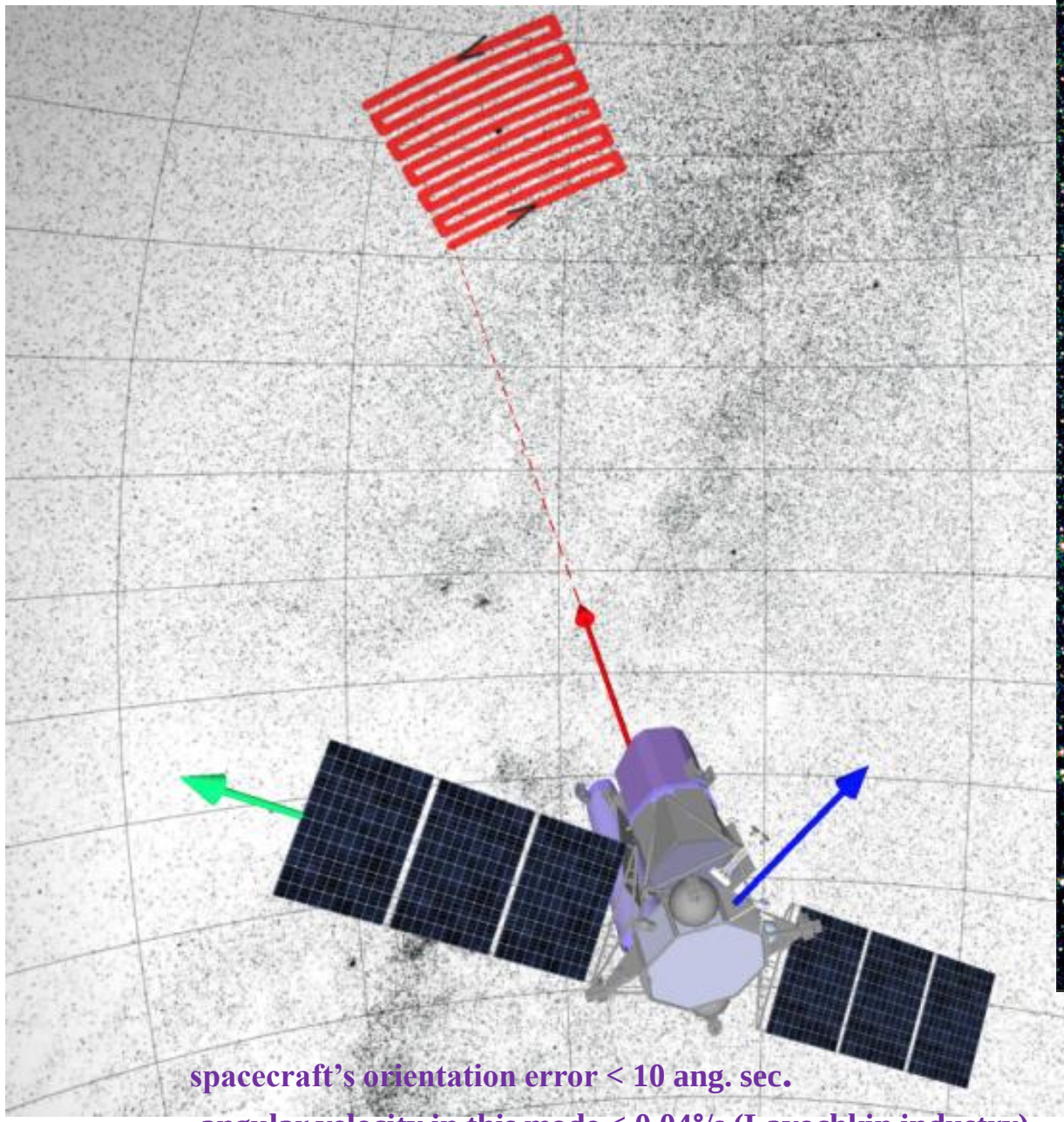
The SRG/eRosita maps of the hemisphere analyzed by the Russian eROSITA consortium

Left side: hot gas emission above the Plane of the Galaxy (halo, local Bubble?, boundary of Heliosphere?).
Strong absorption of X-Rays by the cold gas in the Plane.

Right side: much more X-Ray sources on cosmological distances. Hot gas has temperature less than few million K. Weaker absorption near the Plane of the Galaxy (just cross section).



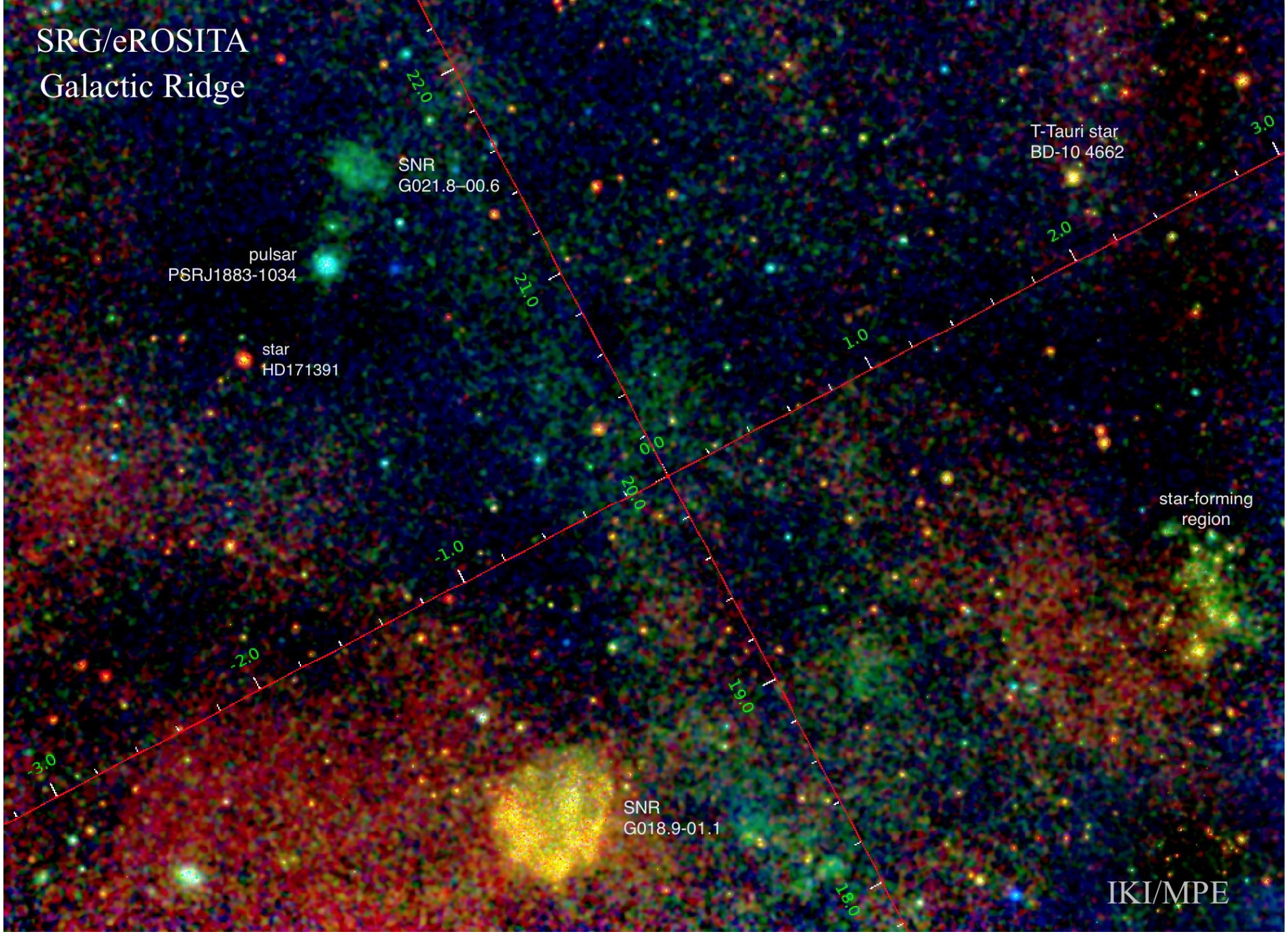
scan of selected regions up to 12.5°×12.5° in size



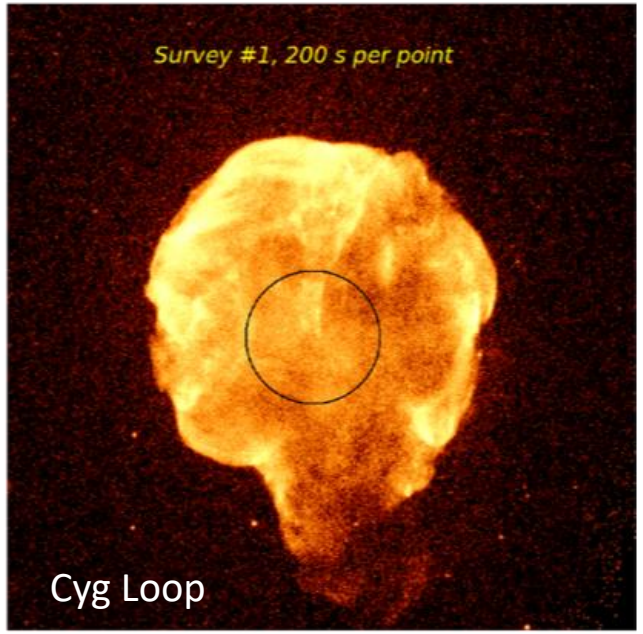
spacecraft's orientation error < 10 ang. sec.

angular velocity in this mode < 0.04°/s (Lavochkin industry)

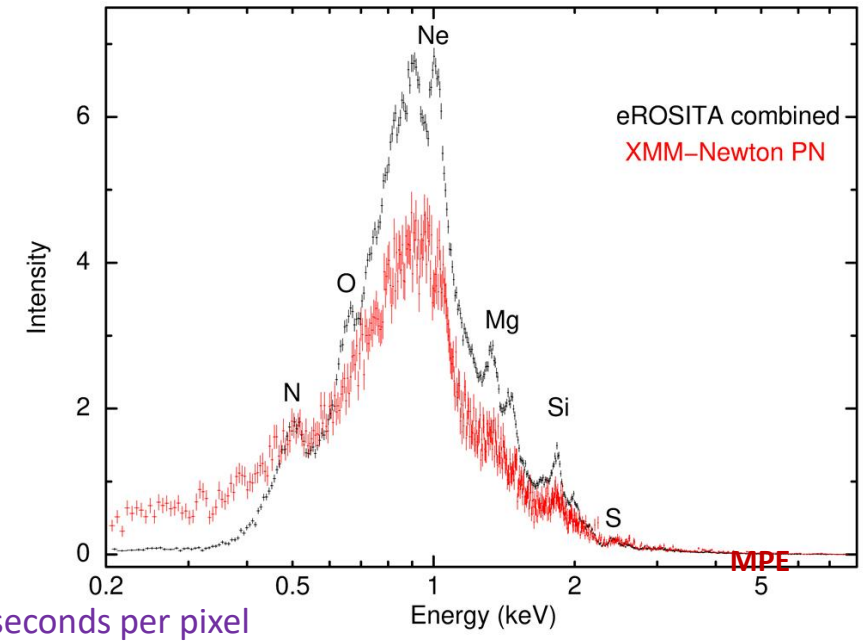
20 sq deg: 6000 X-Ray sources, 200 extended, 185 confirmed clusters of galaxies (spectroscopic z for 150); Rodion Burenin, Marat Gilfanov, Rodion Burenin, Sergej Bykov et al



25 sq deg in 20 degrees from the Galactic Center (Marat Gilfanov et al)

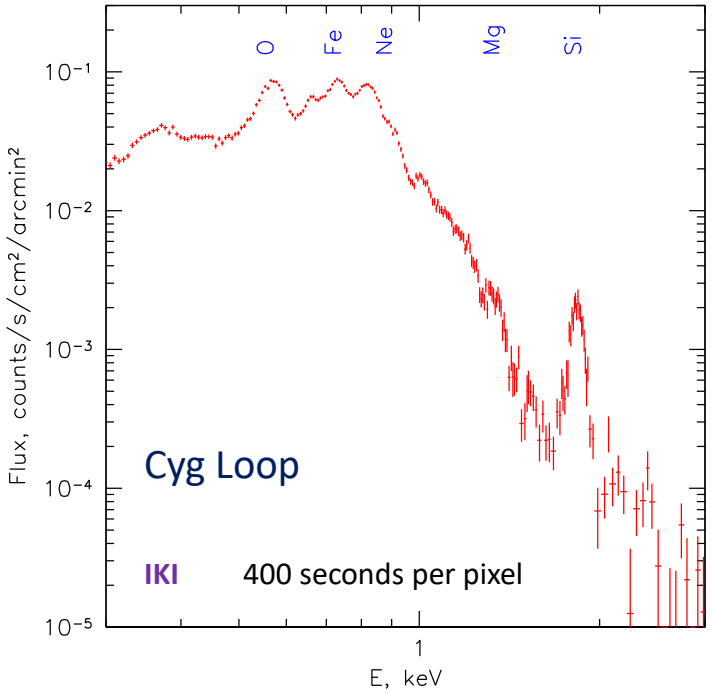


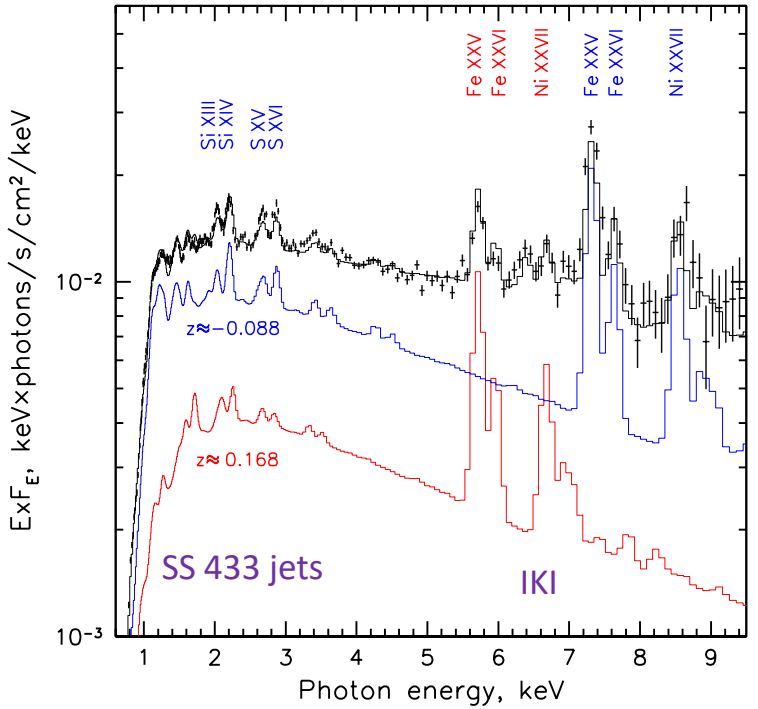
SN 1987A in the LMC



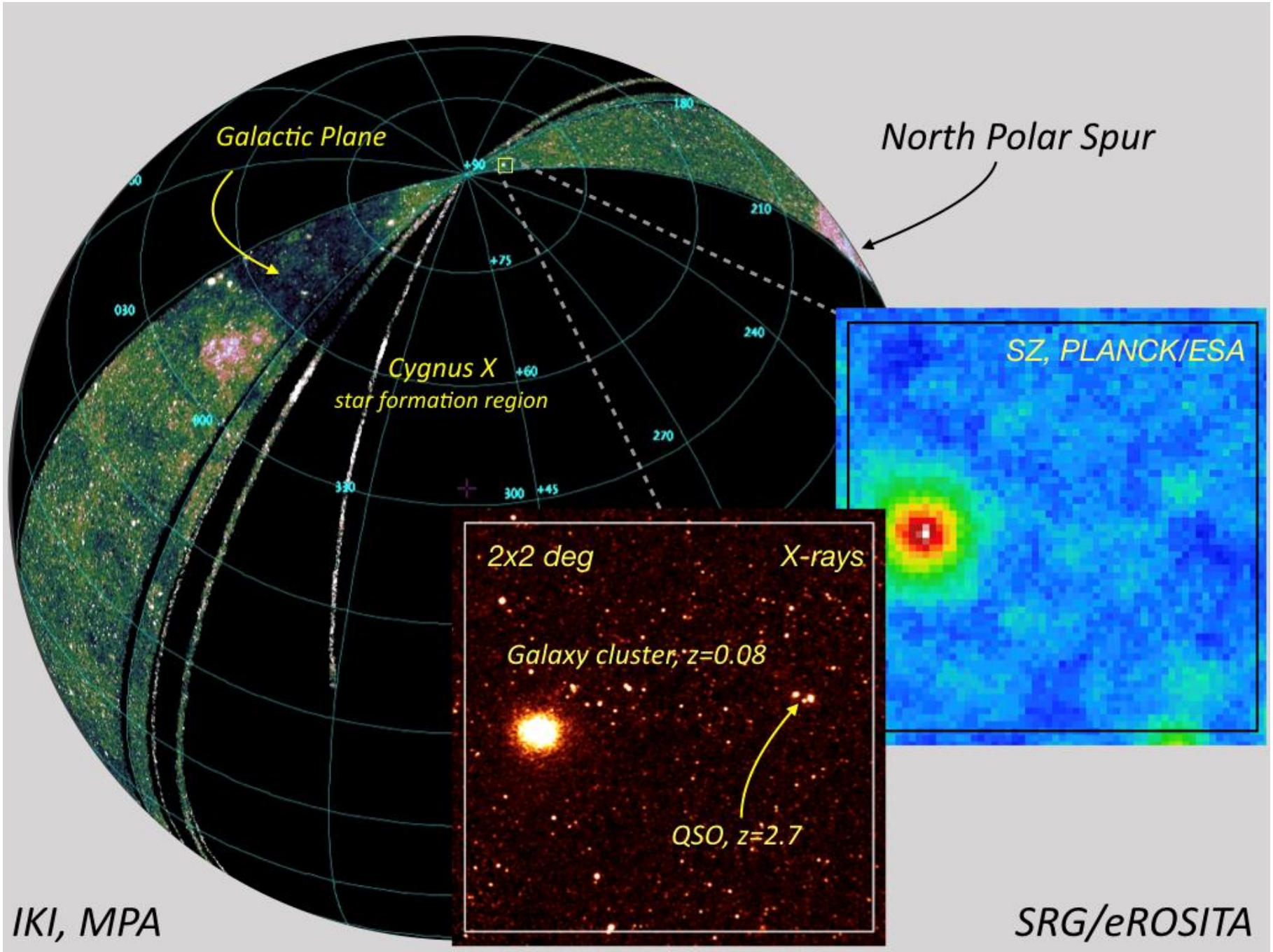
Spectroscopy capabilities of SRG/eRosita

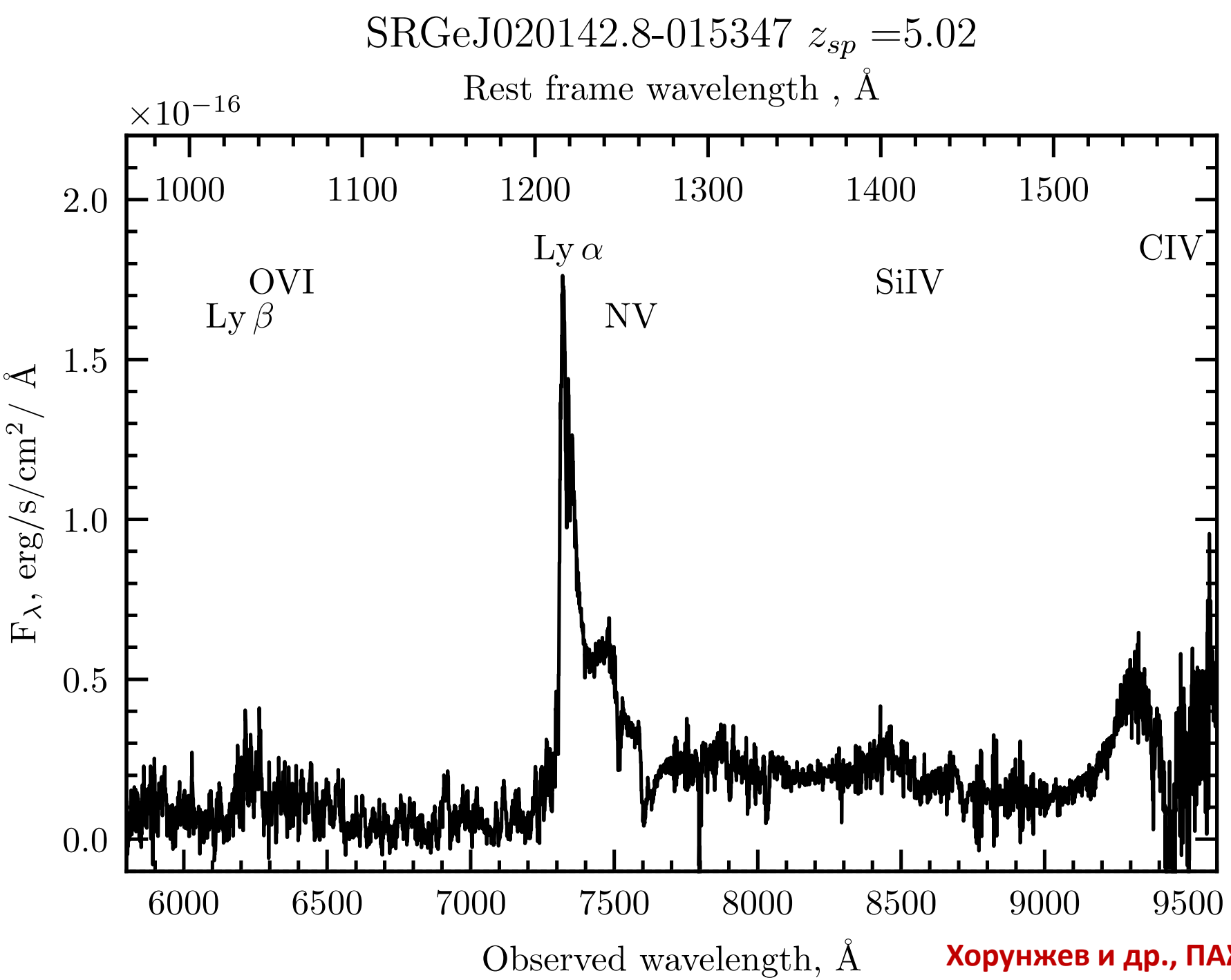
several Kseconds per pixel





Now whole sky is covered four times and 10 % of the sky is covered during current fifth survey



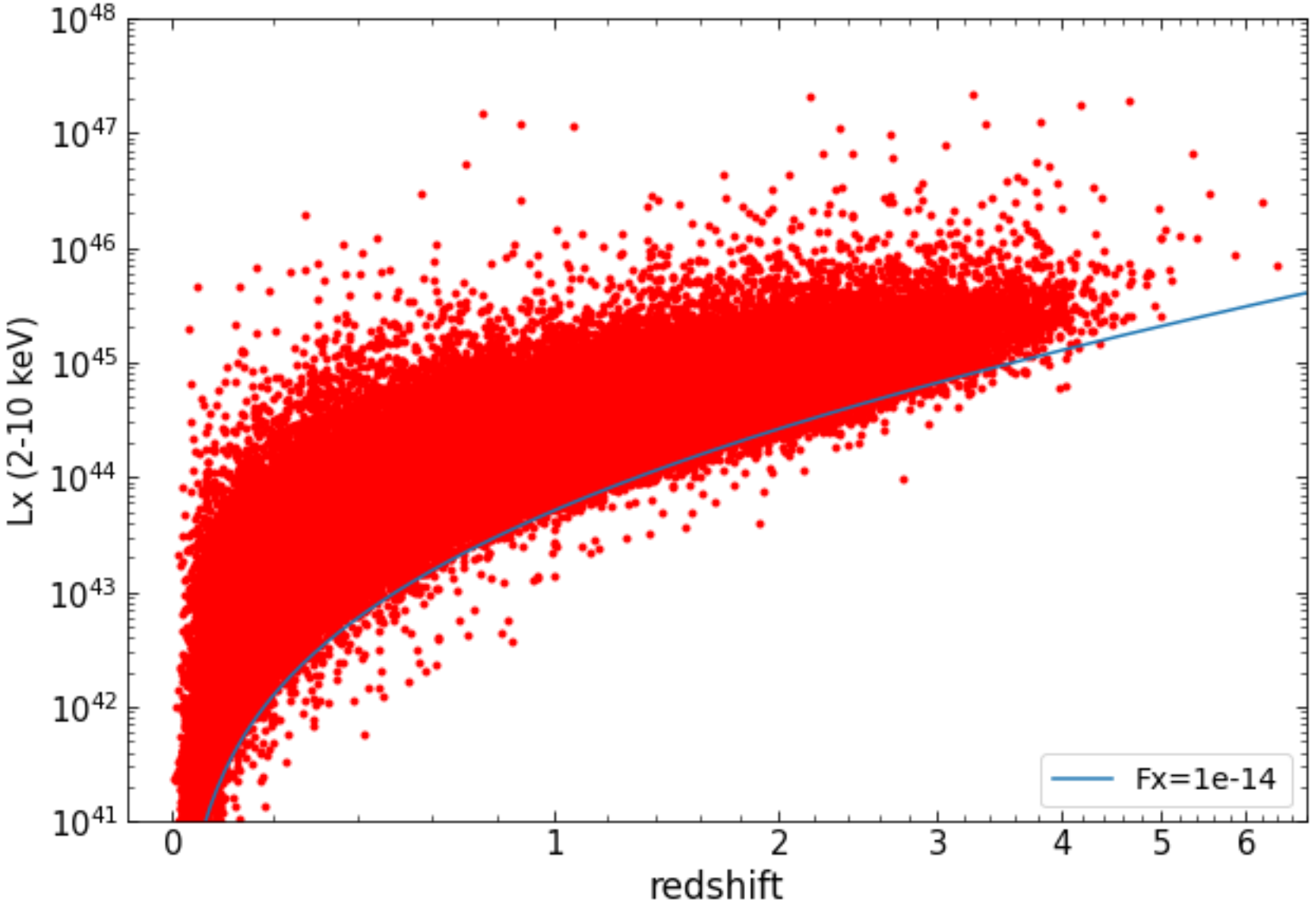


Павел Медведев открыл рентгеновский квазар с красным смещением z=6.18

Хорунжев и др., ПАЖ, 2, 2022

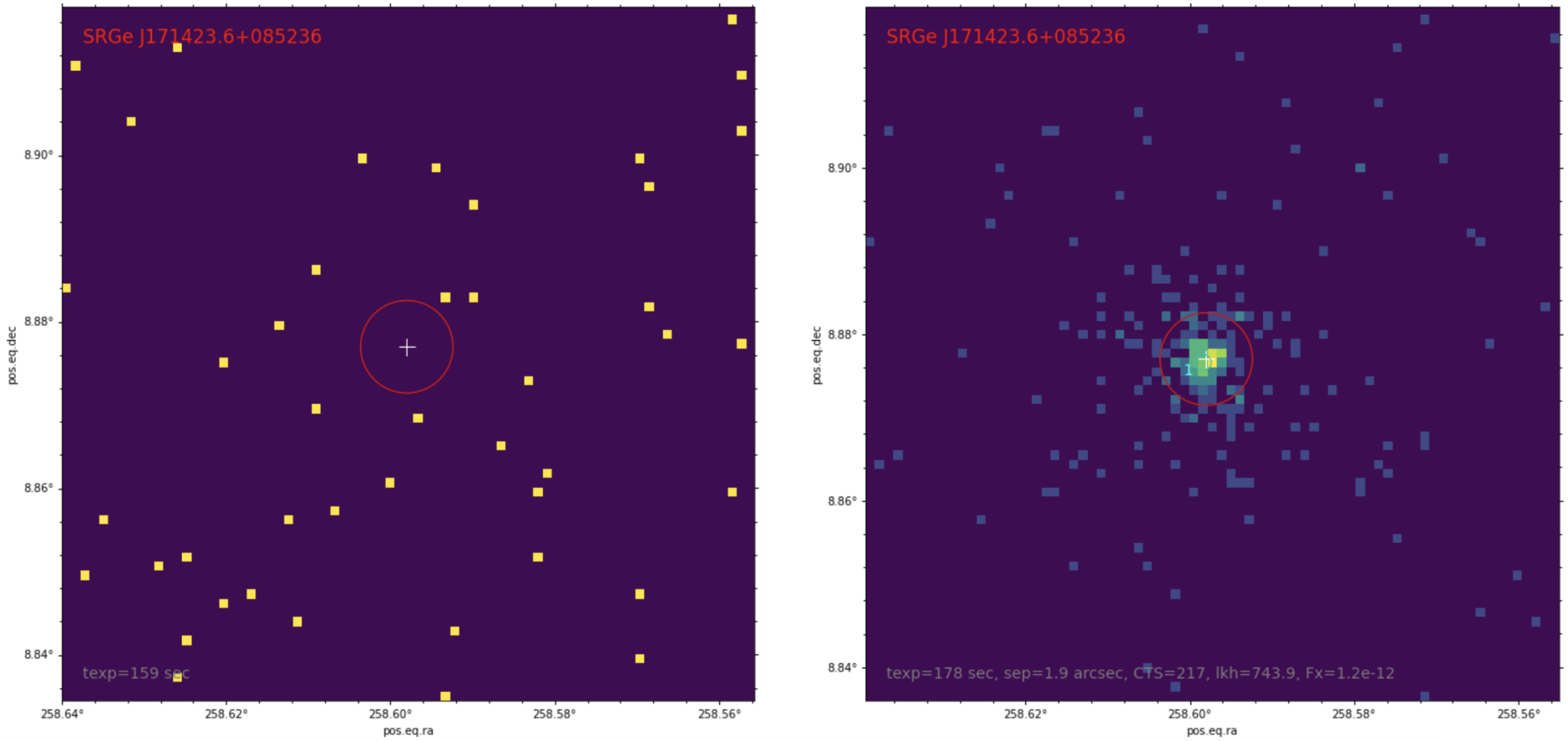
БТА, 6 м

SRG/eRosita **140,094 X-ray selected quasars, blazars and AGN with available redshifts**



M. Gilfanov, S. Sazonov, P. Medvedev, A. Meshcheryakov et al

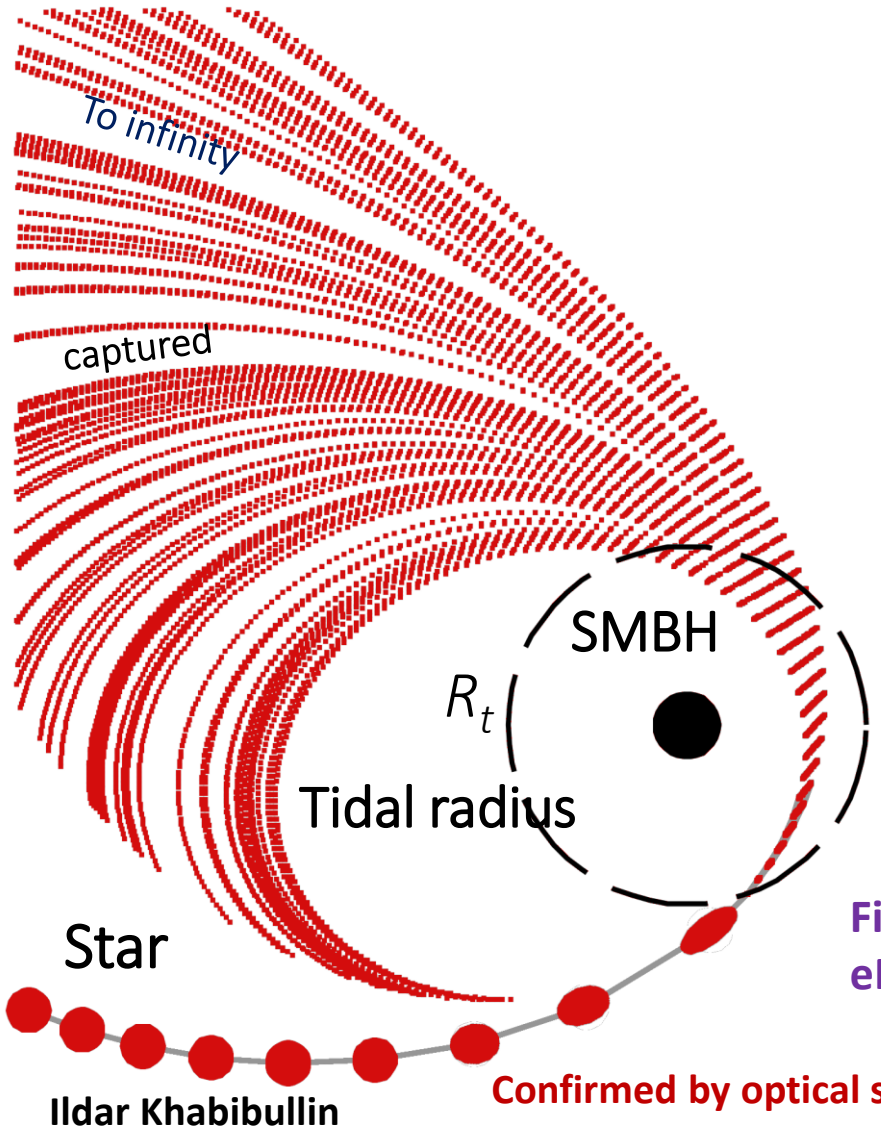
Extragalactic transients

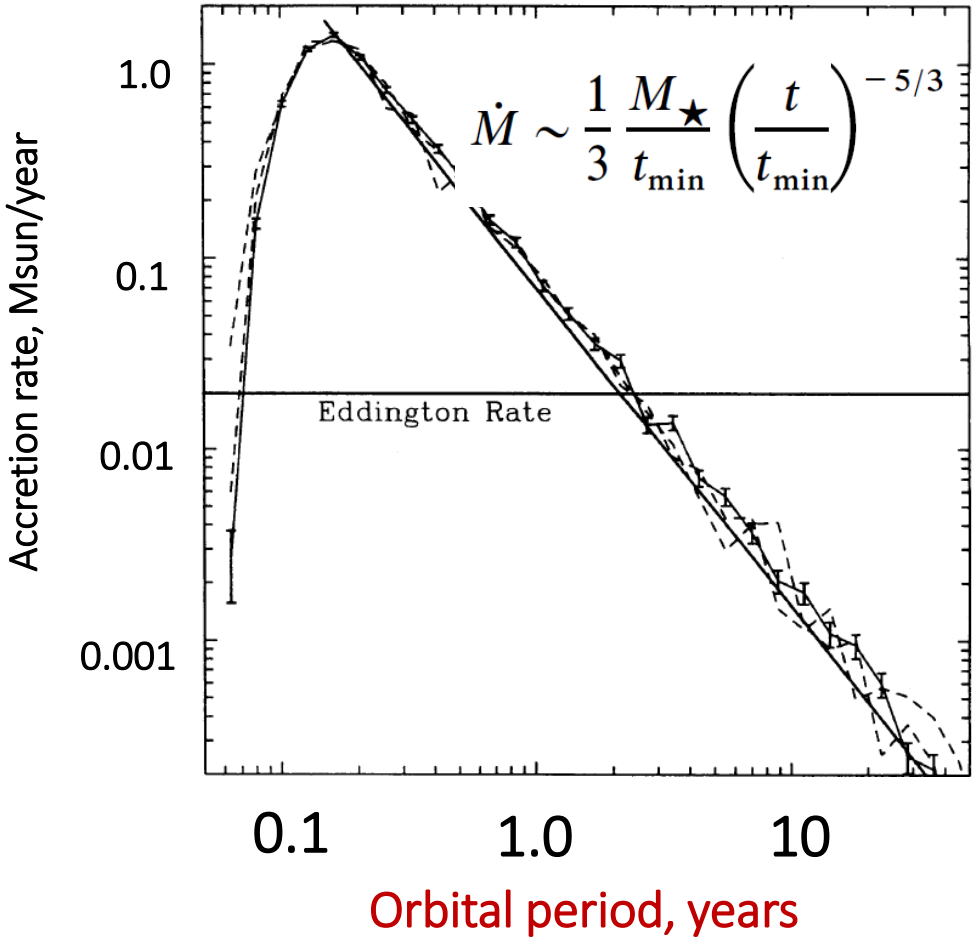


Typically we **detect ~3-5 objects per day changing their flux by >10 times** (stars, AGN, X-ray binaries in the Milky Way).

On average, we detect one good TDE candidate per ~10 days. They are being followed up by telescopes in Russia, Palomar, Keck, ZTF

Tidal star disruption by a supermassive black hole (TDE)





We have now more than 50 good TDE candidates

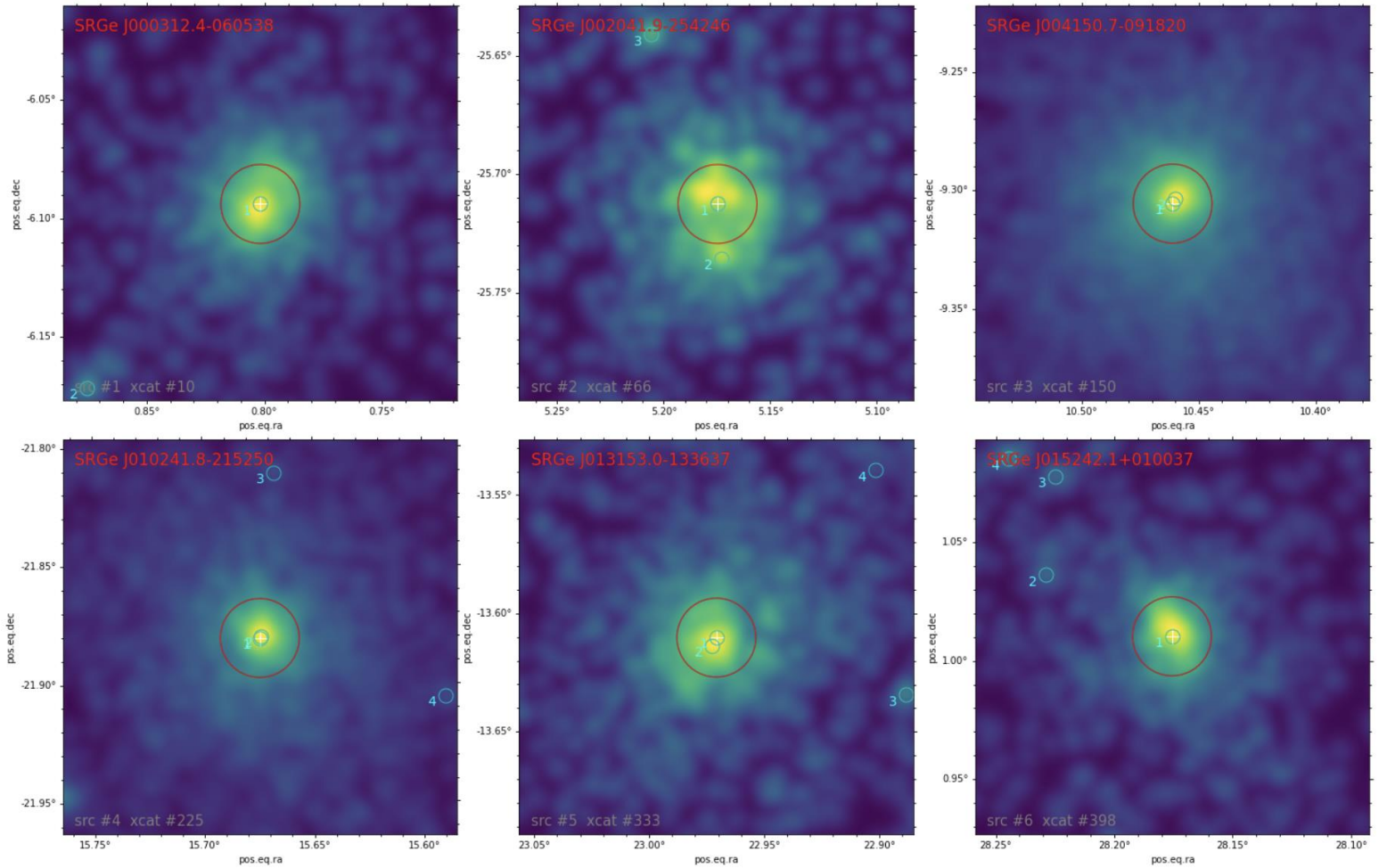
First catalog of 13 TDE events, discovered by SRG/ eRosita. S. Sazonov, M. Gilfanov et al, MN RAS, 2021

Confirmed by optical spectroscopy, BTA, RTT150, AZT33IK,Keck,Palomar etc

Clusters of galaxies,

discovered by SRG/eRosita
as extended X-ray sources

Half of the sky



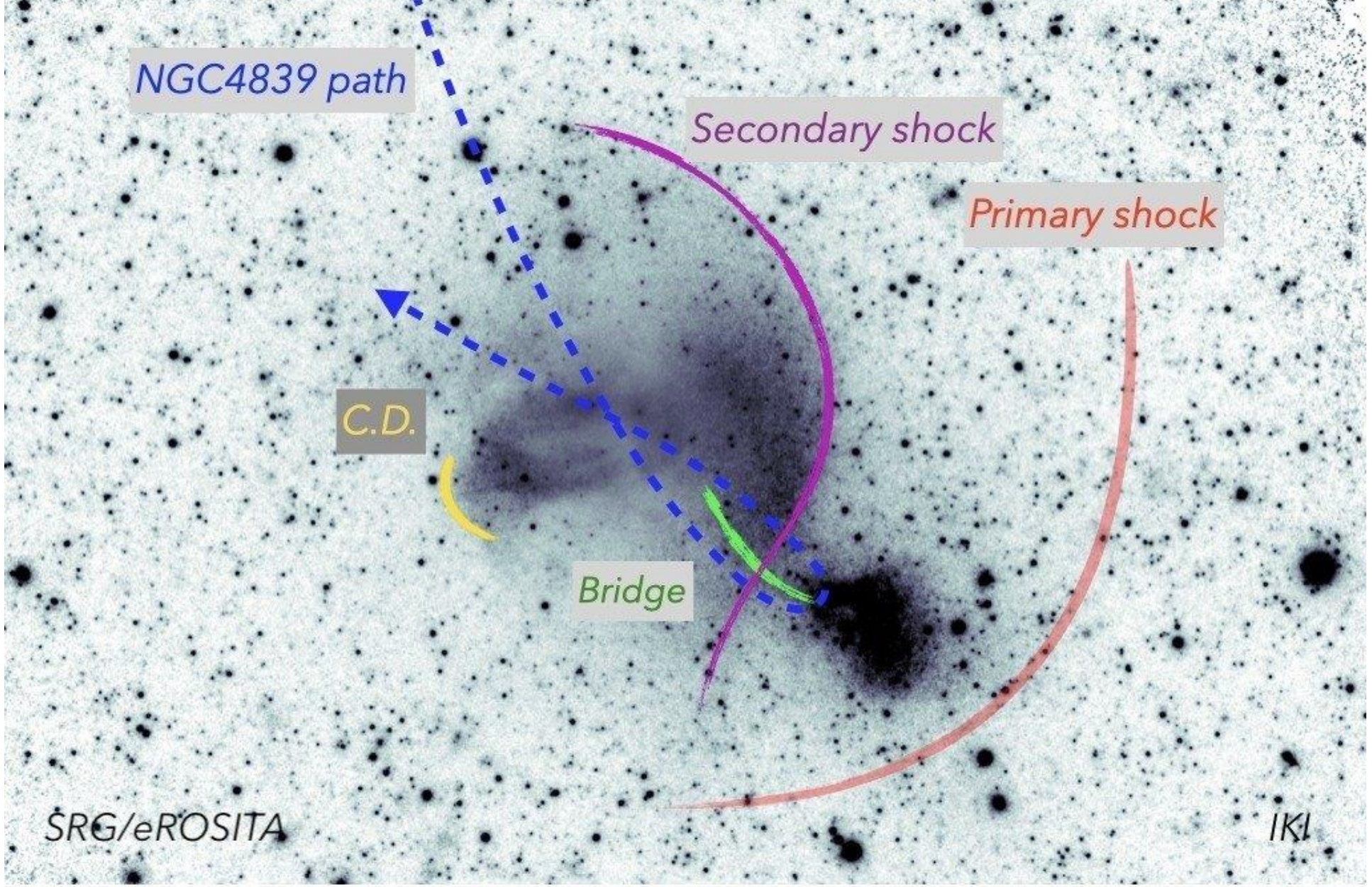
Number of X-Ray clusters

(0<l<180):

	$\geq 5\sigma$	$> 4\sigma$
Sky survey 1	7,500	10,500
surveys 1+2	14,000	19,500
surveys 1+2+3	18,800	25,500
survey 1+2+3+4	23,200	31,500

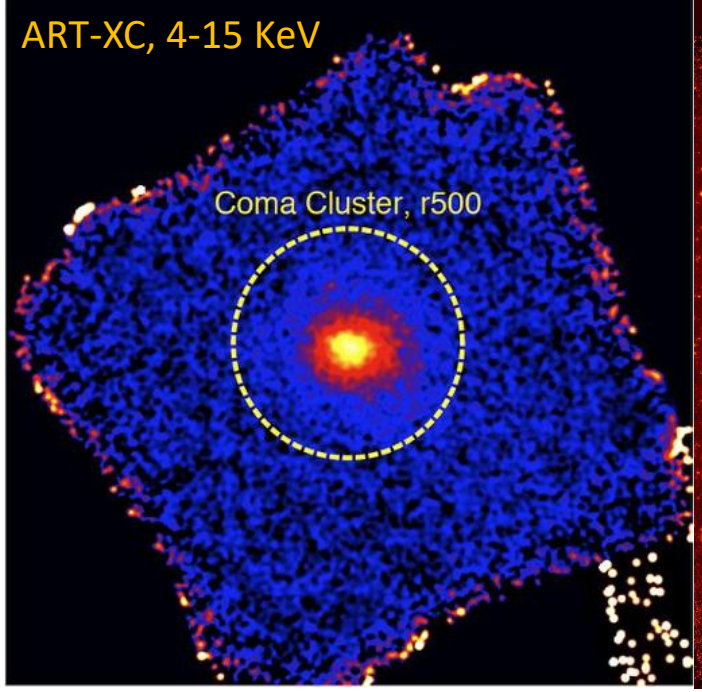
eRosita after 8 sky surveys should discover majority of the massive clusters of galaxies in the »observable part of the Universe. : 50,000 clusters with mass M>2⇦10^{14} M$_\odot$ on the half of the sky or ~ 100,000 clusters of galaxies with many nearby grupp of galaxies)

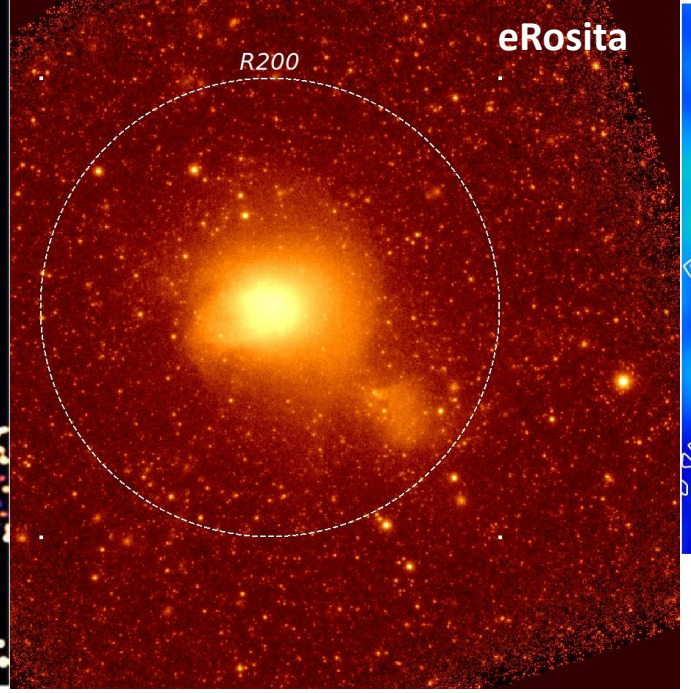
Marat Gilfanov and catalog group

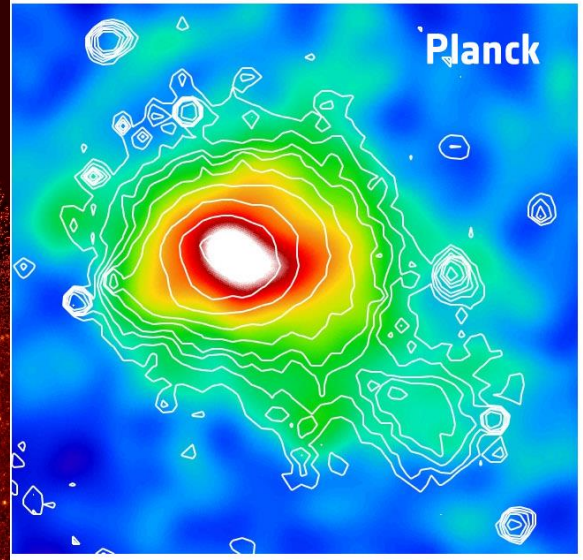


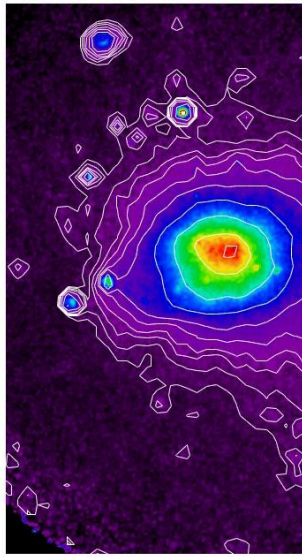
Churazov et al, A&A, 2021

Coma cluster, flattened image and suggested trajectory of the group NGC 4839







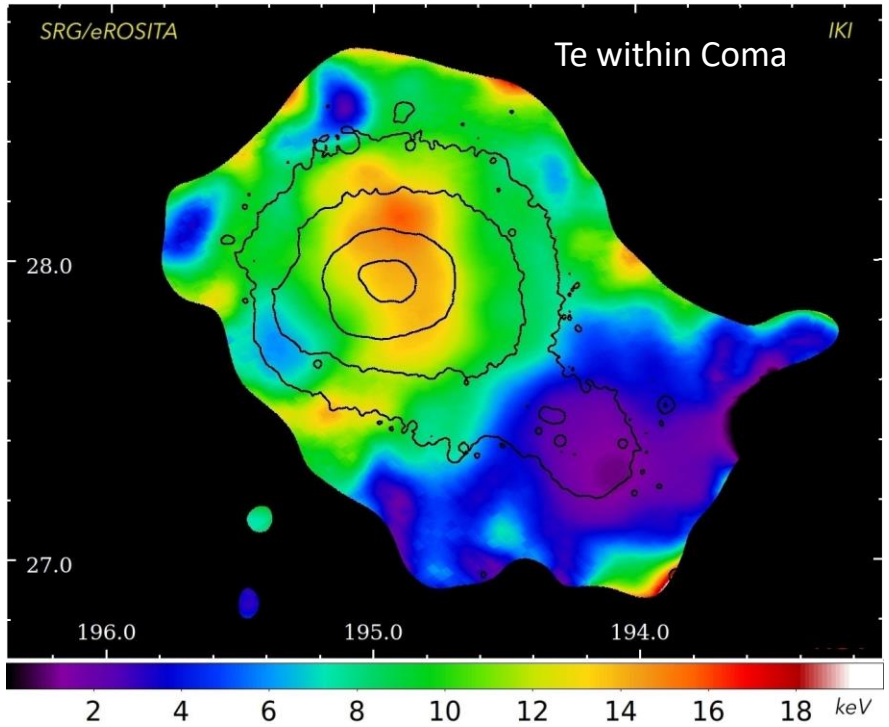


Excellent SZ-image

Ratio of “y” parameter on the Planck SZ map
to the X-Ray surface brightness (eRosita, 0.4-2 KeV)
opens the possiblity to look for the distribution
of Te over the whole Coma (under assumption of
the gas density distribution)

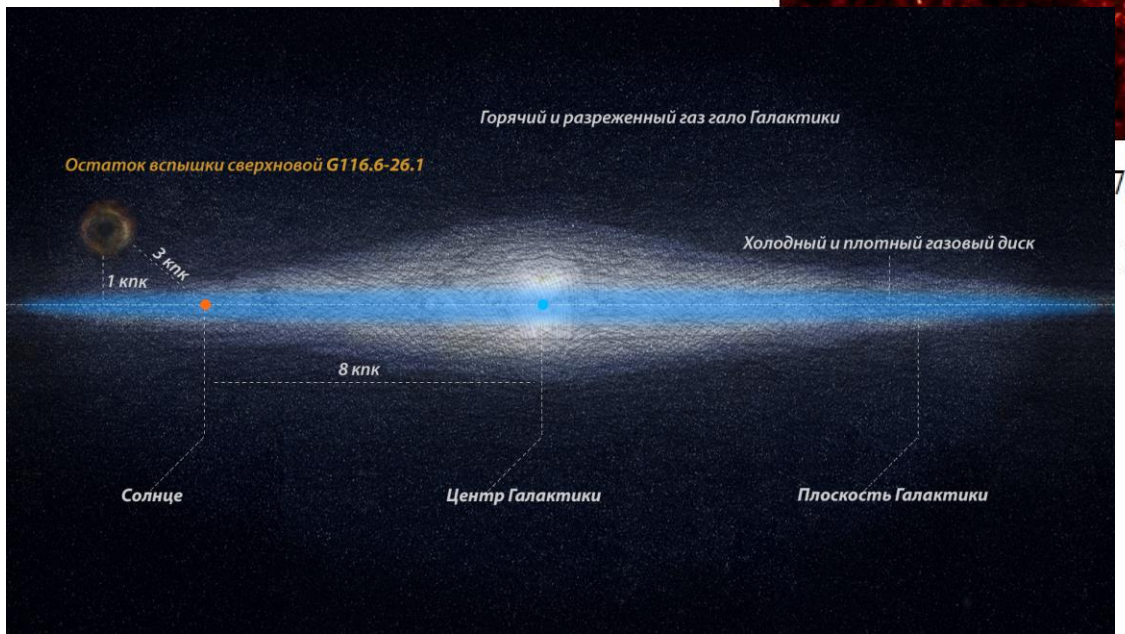
$$k\tilde{T} \approx \frac{y}{I_X}\frac{m_e c^2}{\sigma_T}\frac{1}{4\pi}\frac{1}{(1+z)^2}\epsilon_c\left(\frac{n_H}{n_e}\right)\frac{\int n_e^2 dz}{\int n_e dz}$$

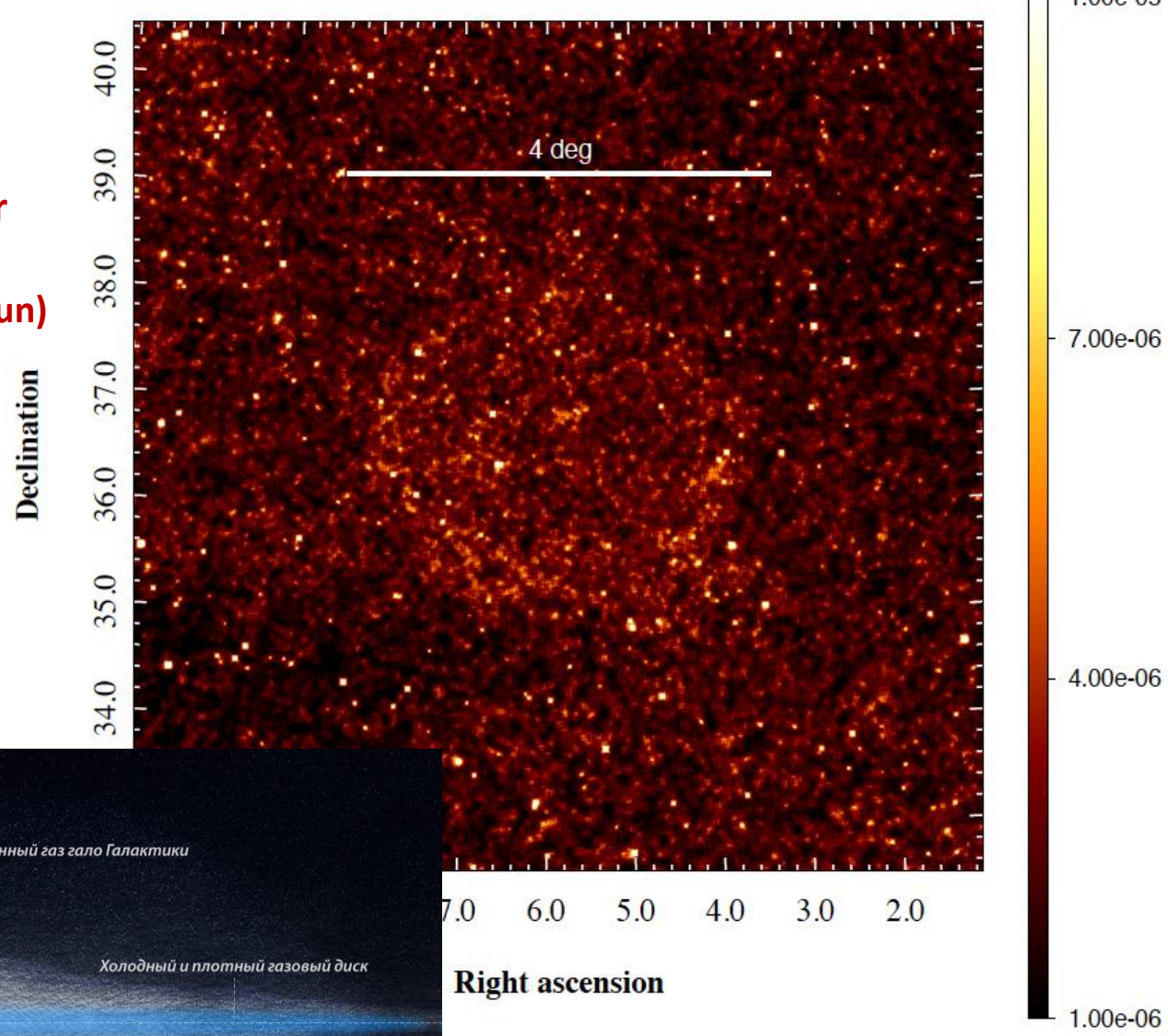
Churazov et al, A&A, 2021



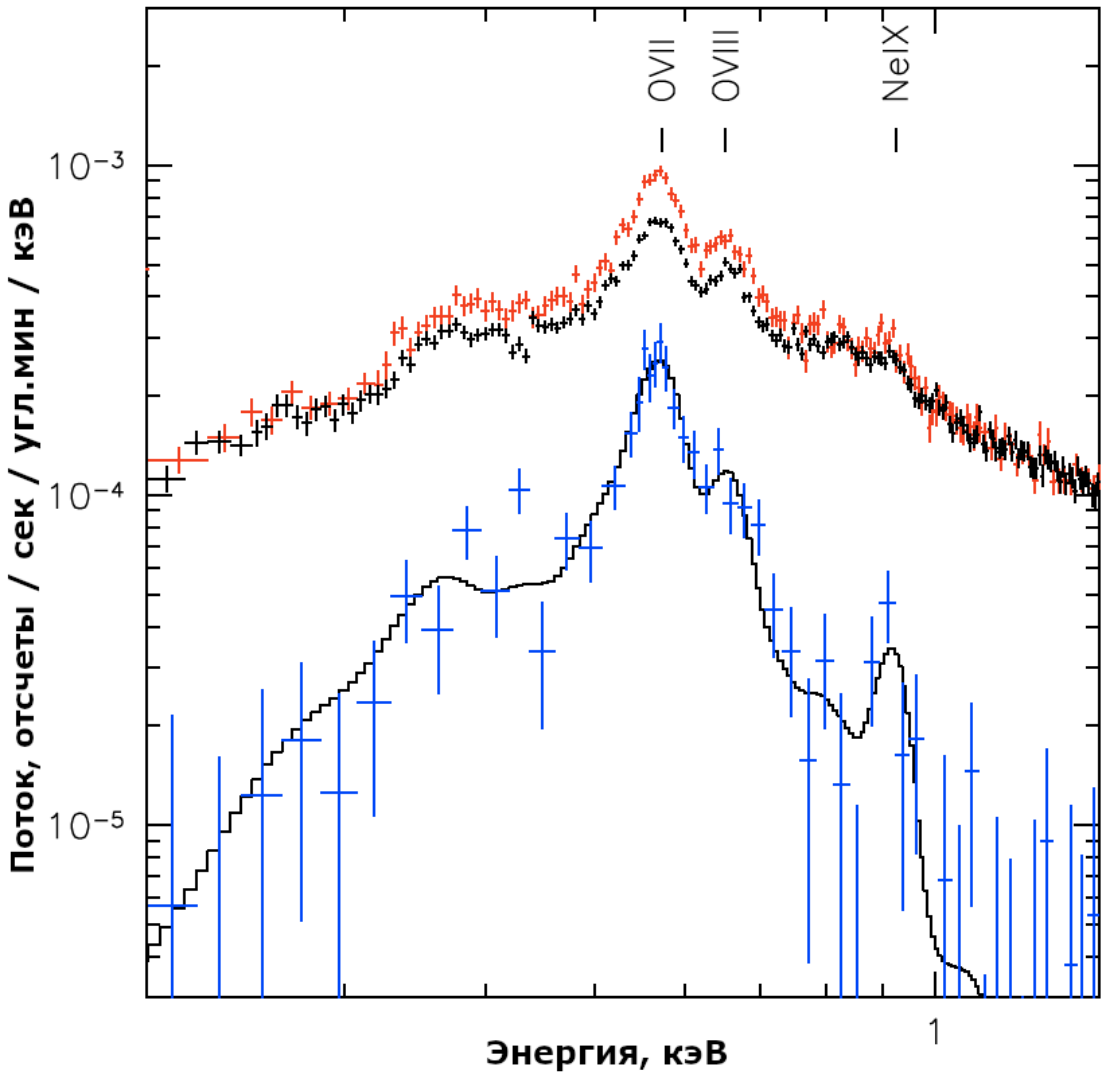
Very large remnant of the thermonuclear supernova explosion in the halo of our Galaxy (1.3 kpc above plane of the Galaxy, 3kpc from the Sun)

No traces in radio, gamma-rays, optical or infra-red spectral bands





Churazov et al, MN RAS, 2021



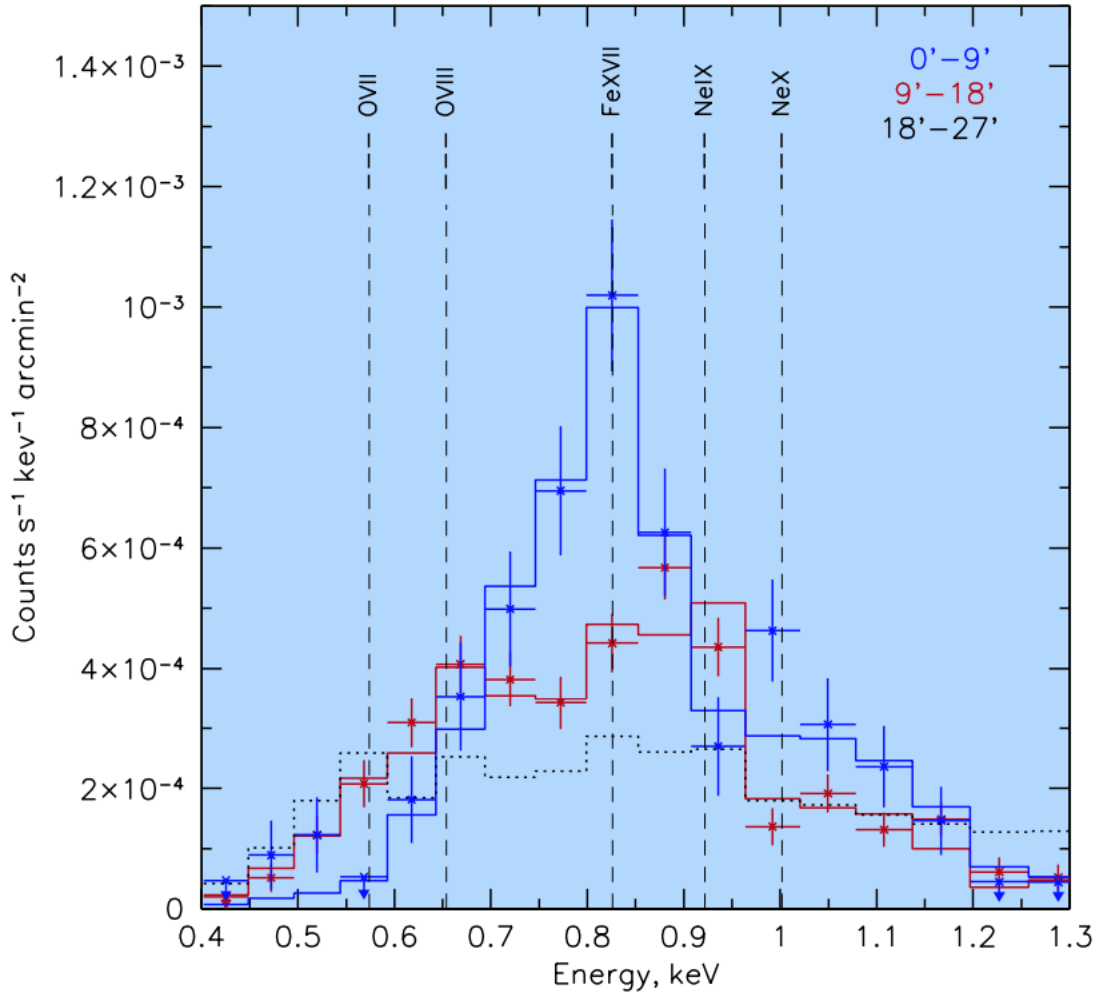
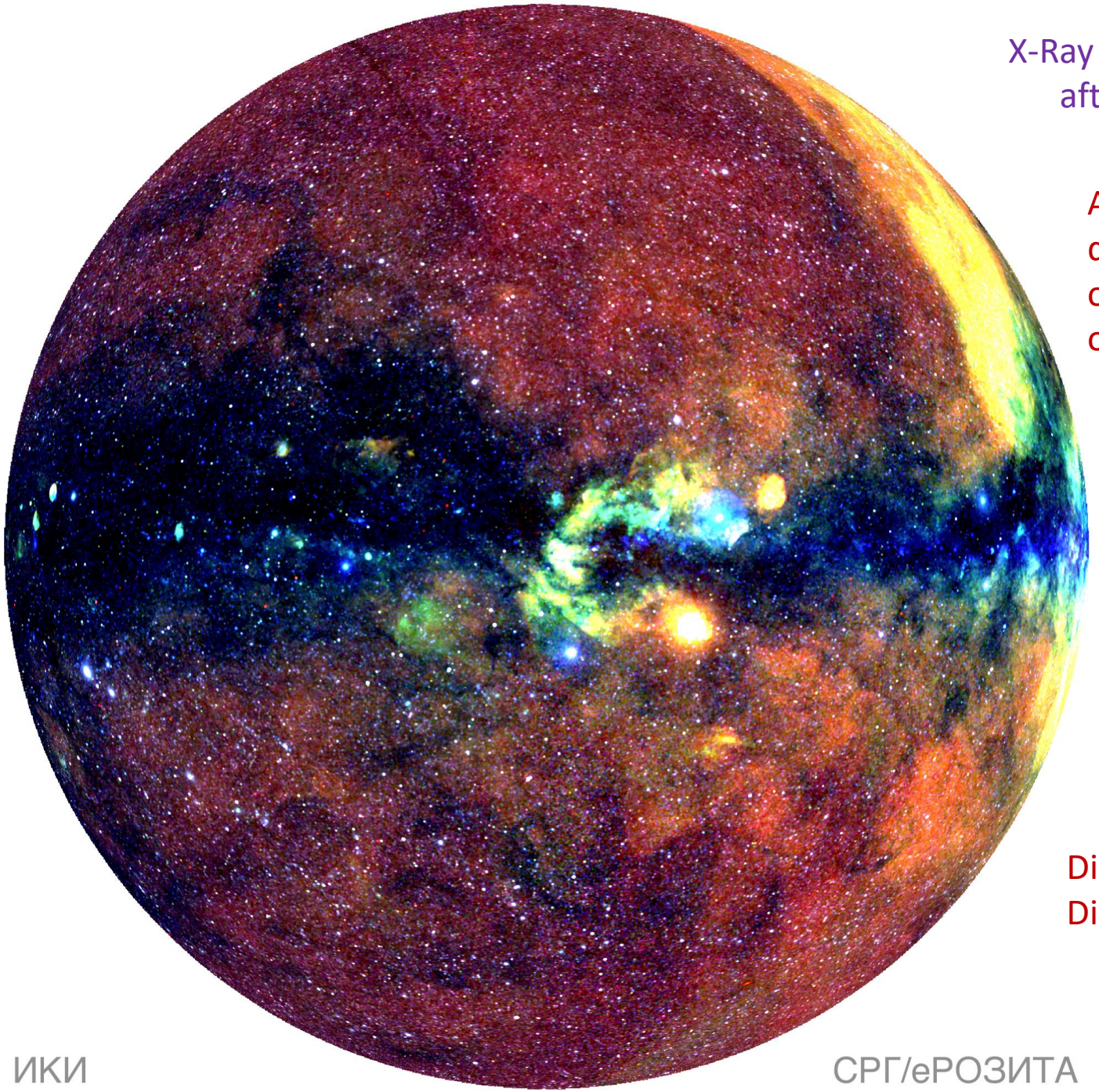


Figure 6. A zoom-in in the spectra (after astrophysical background subtraction) in the 0'-9' (blue) and 9'-18'(red) rings within the 0.4-1.3 keV band. The positions of the most prominent emission lines (O VII at 574 eV, O VIII at 654 eV, Fe XVII at 826 eV, Ne IX at 922 eV and Ne X at 1002 eV) are marked and labelled accordingly. The subtracted astrophysical background (and foreground) emission is shown by black dotted line.



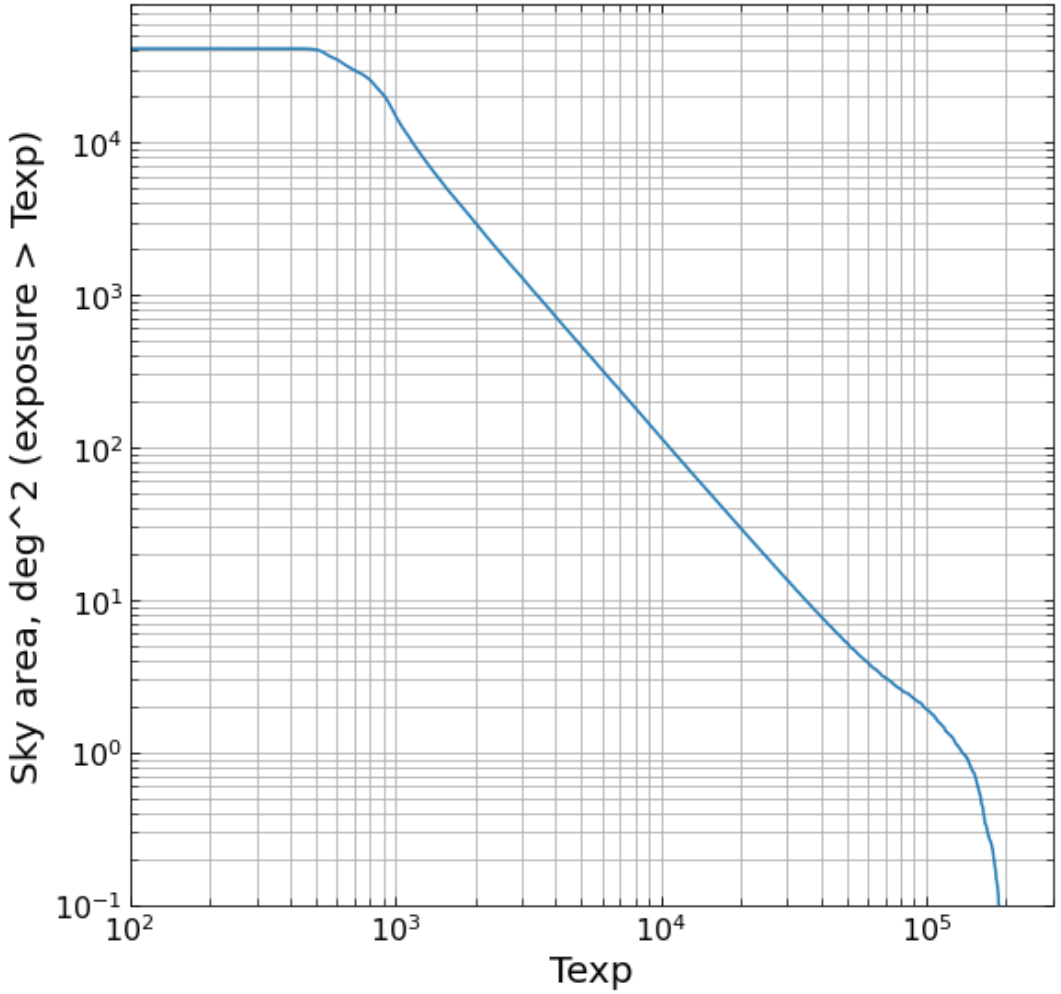
X-Ray map of one hemisphere
after two sky surveys

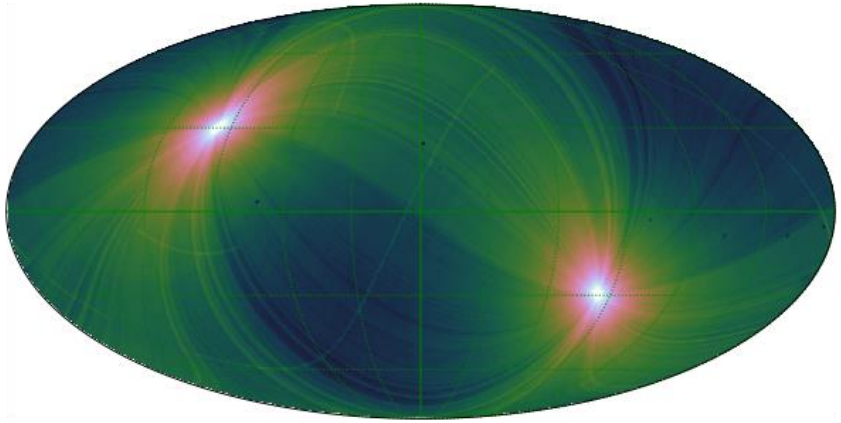
Amount of the sources
doubled: nearly
one million
on the one hemisphere

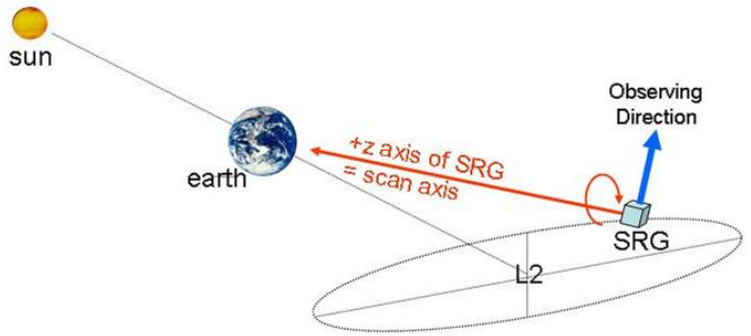
Strong variability:
tens of thousands
objects changed their
brightness during half
a year!

Discovery of the Tidal
Disruption Events (TDE)

Exposition map: 4 sky surveys: 12 Dec. 2019 –19 Dec. 2021







Catalogs scientific working group, SRG/eRosita, IKI; M. Gilfanov, P. Medvedev et al.

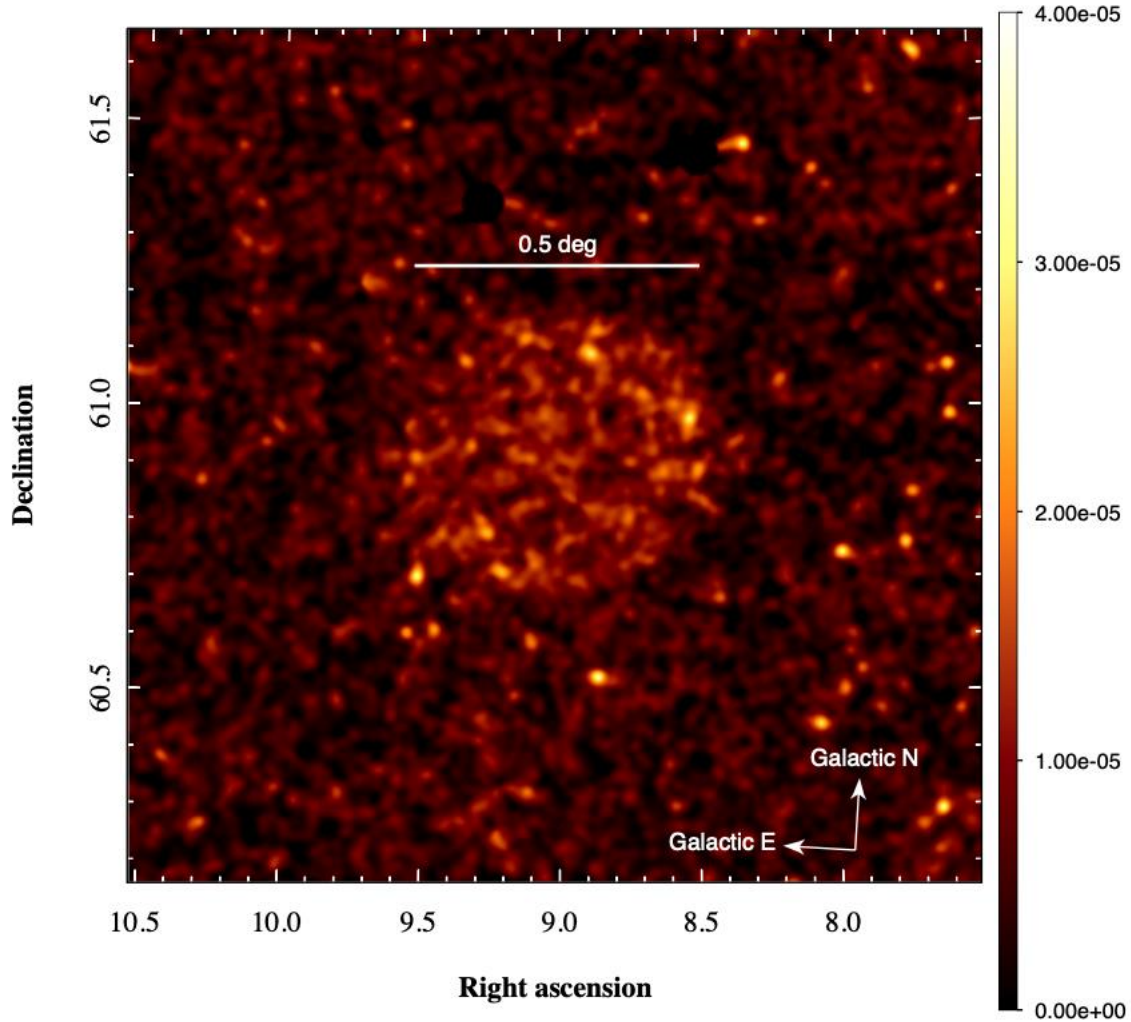
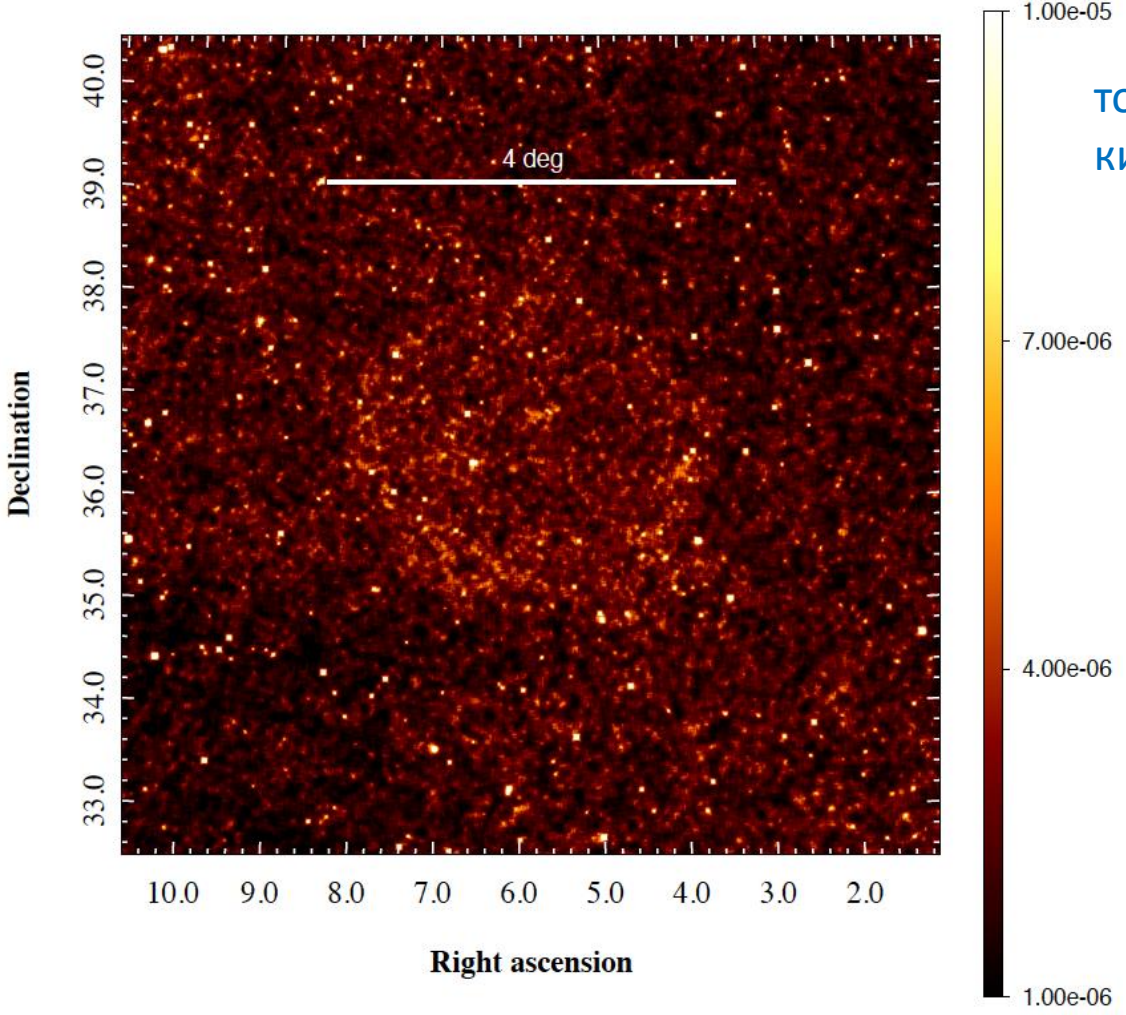
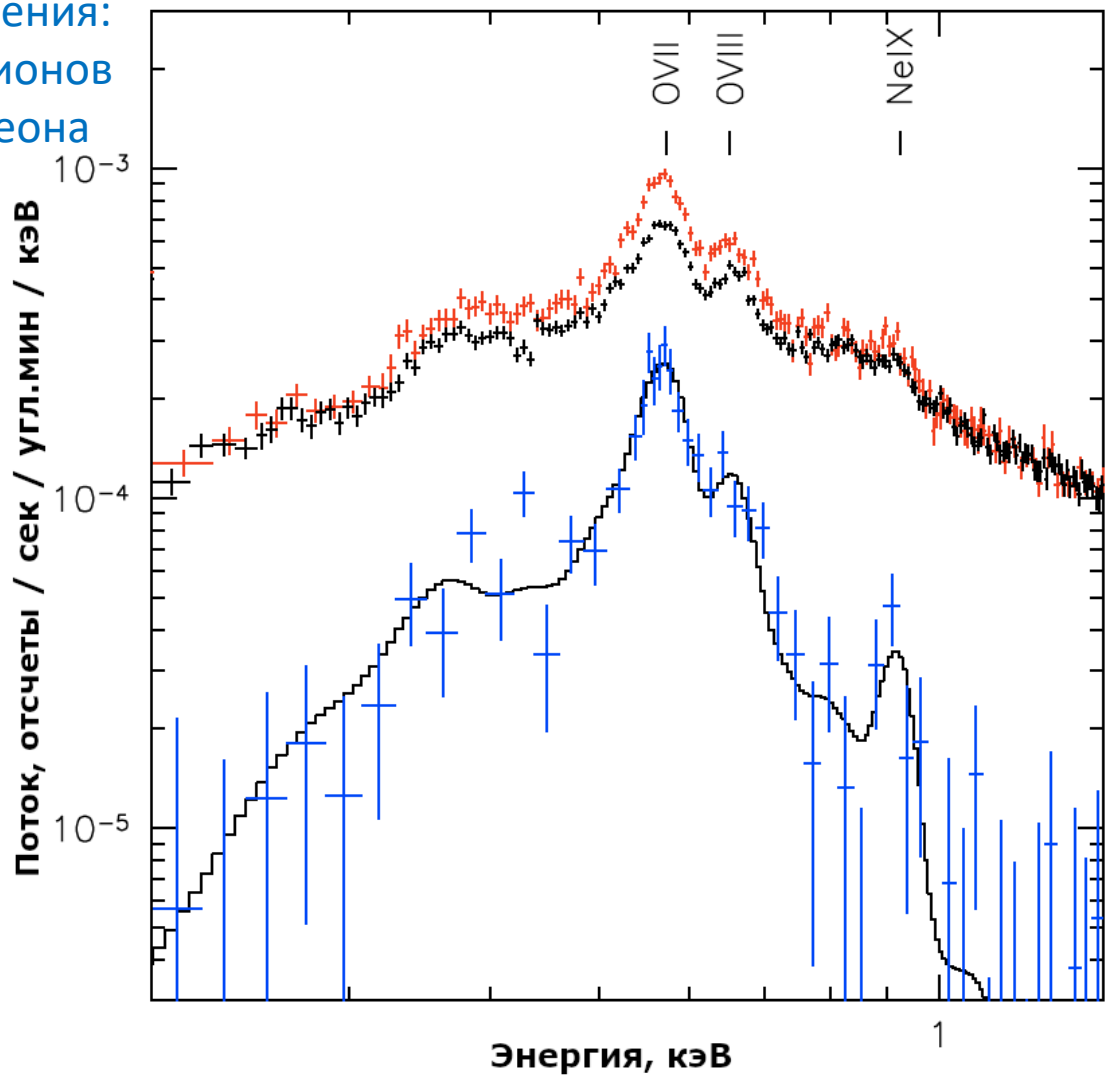


Figure 1. Detector background-subtracted vignetting-corrected image of X-ray (0.4-2.3 keV) surface brightness in the 1.5×1.5 deg field containing the newly discovered SNR candidate SRGe J003602.3+605421=G121.1-1.9 obtained by *SRG*/eROSITA after four surveys. The image was smoothed with a σ=30" gaussian filter after masking point-like and mildly extended sources with the 0.5-2 keV flux above 3×10^{-14} erg s^{-1} cm^{-2}. The white compass shows direction of the Galactic coordinates.



Спектр излучения: только линии ионов кислорода и неона



Большой (~ 4 град) остаток взрыва термоядерной сверхновой в гало Галактики

1.3 кпк над плоскостью, 3 кпк от Солнца

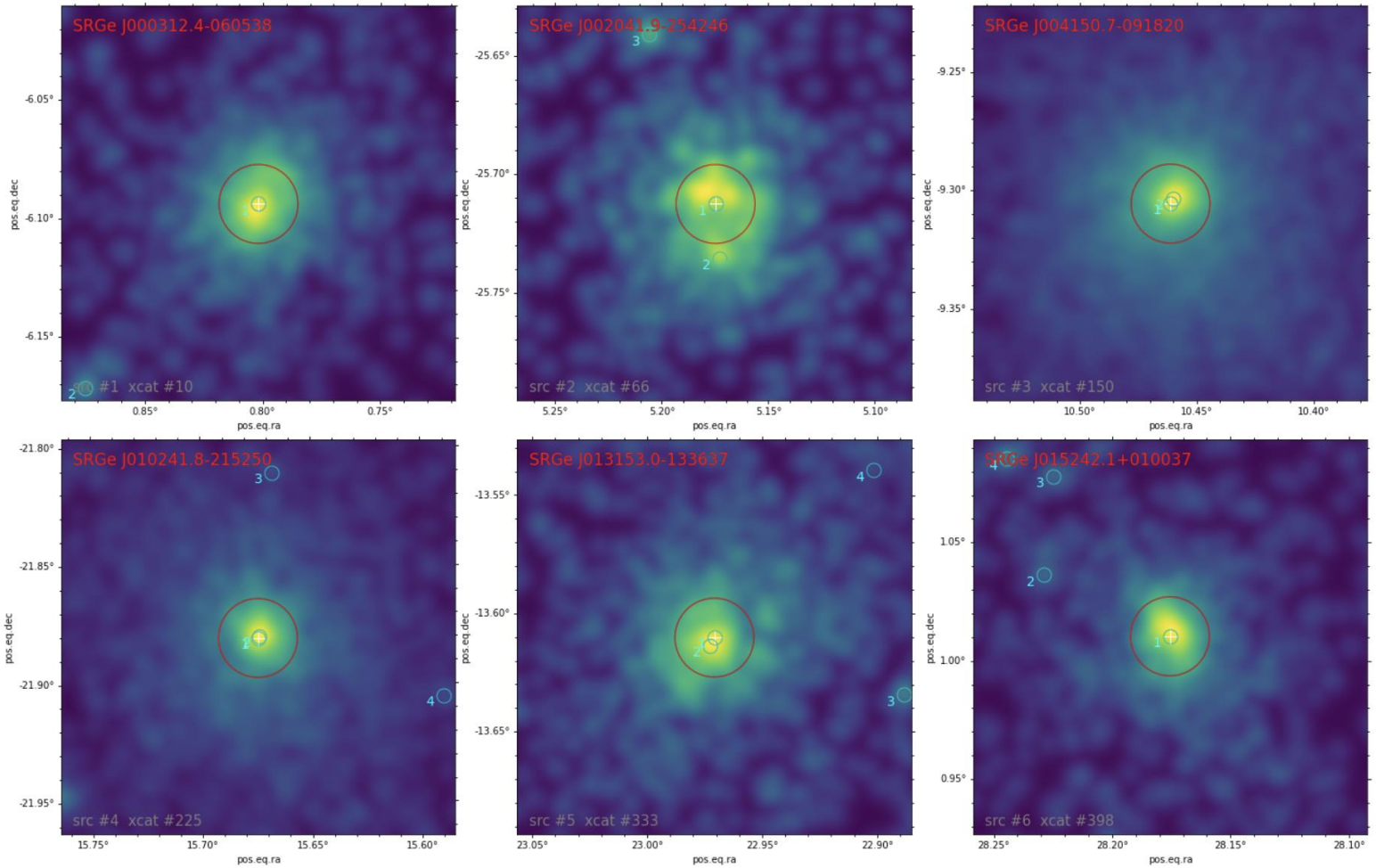
Никаких следов в радио, гамма, оптике или ИК

Пока только eРозита

В статье И. Хабибуллина: о *втором* открытом остатке сверхновой с сильными рентгеновскими линиями ионов железа вблизи 826 эВ

Churazov et al, MN RAS, 2021

Скопления галактик,
обнаруженные по их рентгеновскому излучению
на половине неба
(результаты eРозиты)

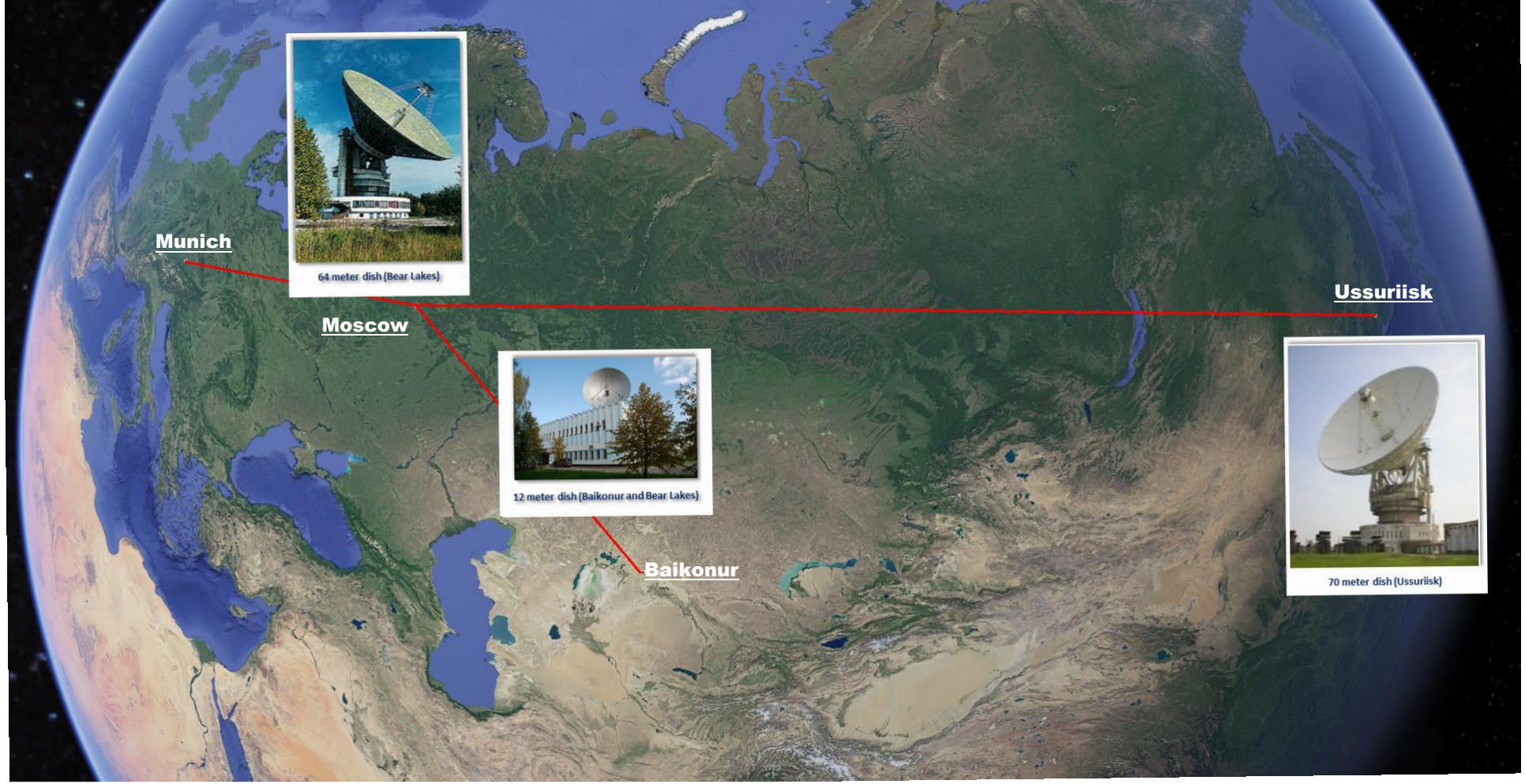


число обнаруженных скоплений (0<l<180):

	$\geq 5\sigma$	$> 4\sigma$
обзор 1	7,500	10,500
обзор 1+2	14,000	19,500
обзор 1+2+3	18,800	25,500
обзор 1+2+3+4	23,200	31,500

ePOЗИТА за 8 сканов должна обнаружить все массивные скопления галактик в наблюдаемой части Вселенной: 50,000 скоплений с вириальной массой $M>2\times10^{14}\ M_\odot$ (всего ~100,000 сколений и групп галактик)

М.Р. Гильфанов и группа по каталогам

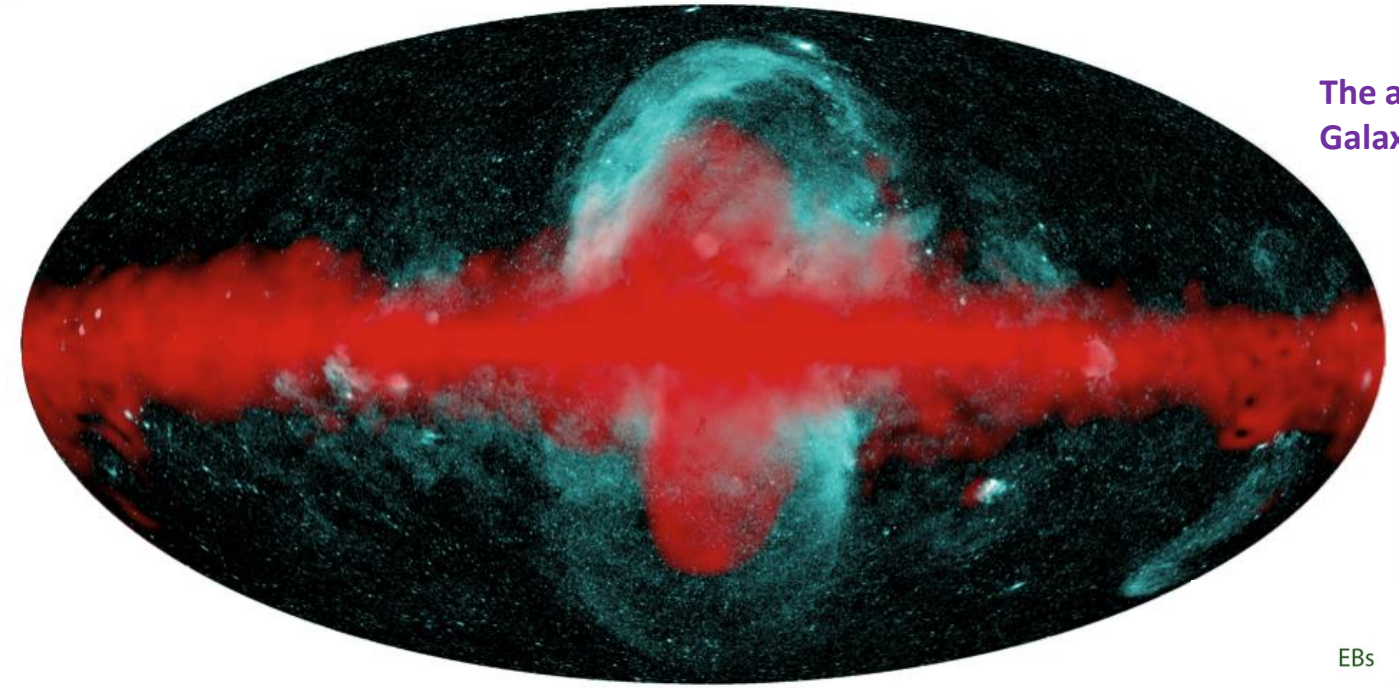


Antennae used by the Center of Deep Space Communications
for everyday work with SRG Observatory and its telescopes

Accretion onto black hole

Gas has angular momentum, turbulent viscosity helps to take it away and permits radial motion and release of gravitational energy

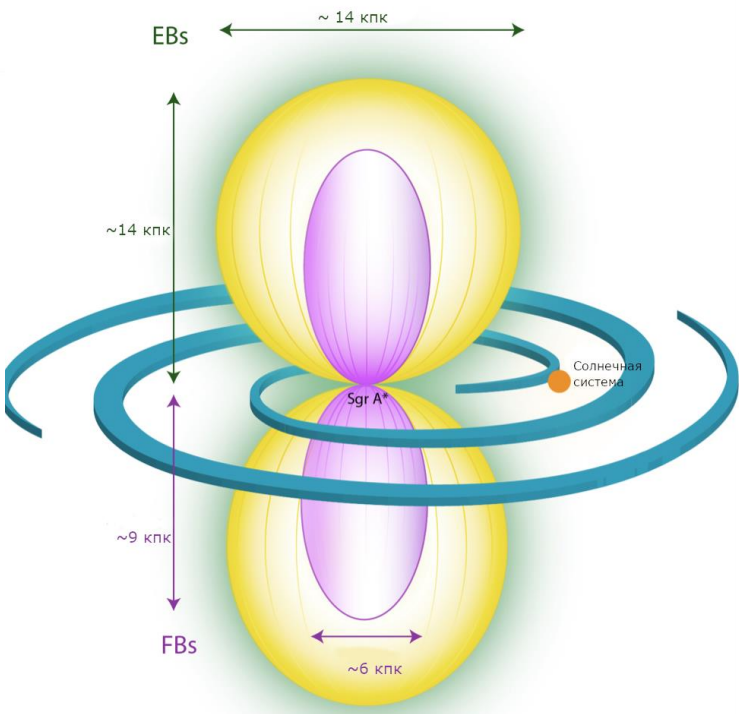
Dissipation of turbulence heats the disk; surface area is small
~ Rg ^2 - X-Rays



«eRosita bubbles»

The activity of the central part of our Galaxy tens of millions of years ago

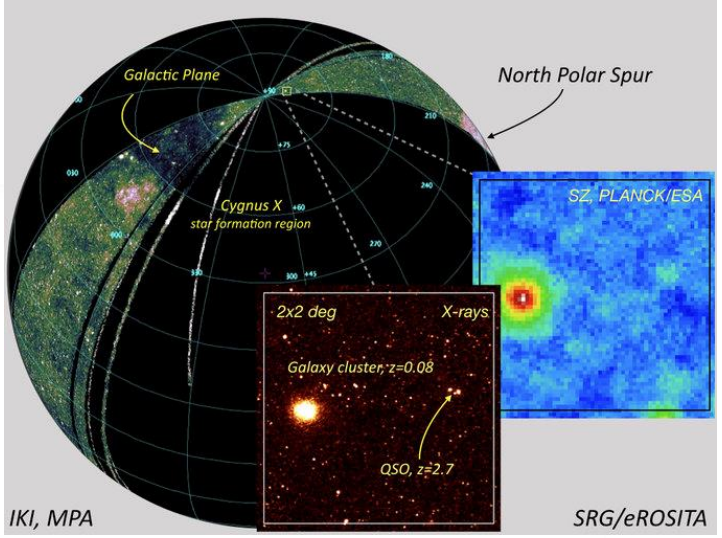
sketch

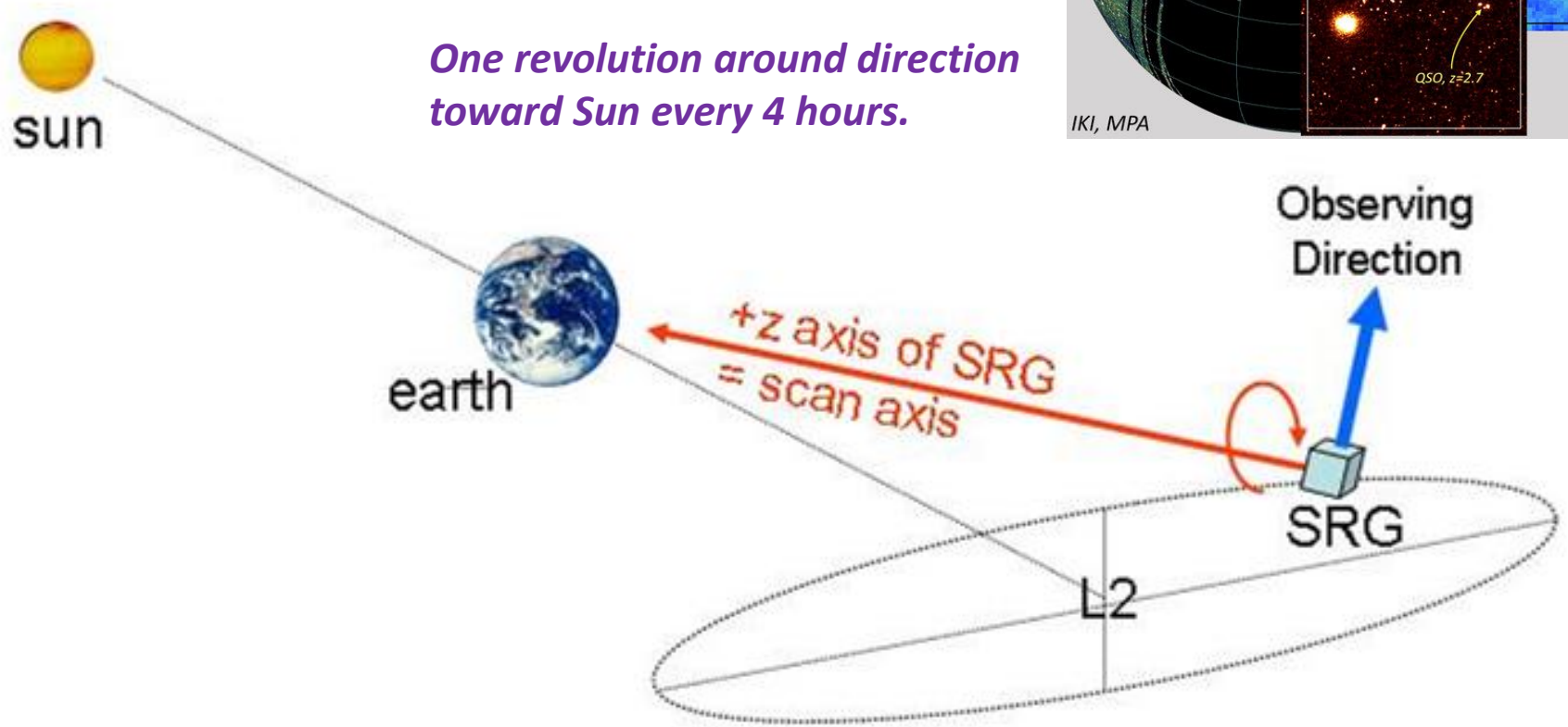


Overlay of maps of our Galaxy obtained by telescopes SRG / eROSITA and Fermi (NASA). Diffuse X-ray radiation recorded by the SRG / eROSITA telescope (0.6–1 keV, indicated by shades of blue), surrounds a region of harder radiation (GeV's), indicated in red, which is called “Fermi bubbles”.

Images from the article P. Predehl, R. Sunyaev, et al., Nature, 2020

Every day the plane of the scan shifts slowly to one degree, following the Sun and leaving one degree wide strip on the sky map



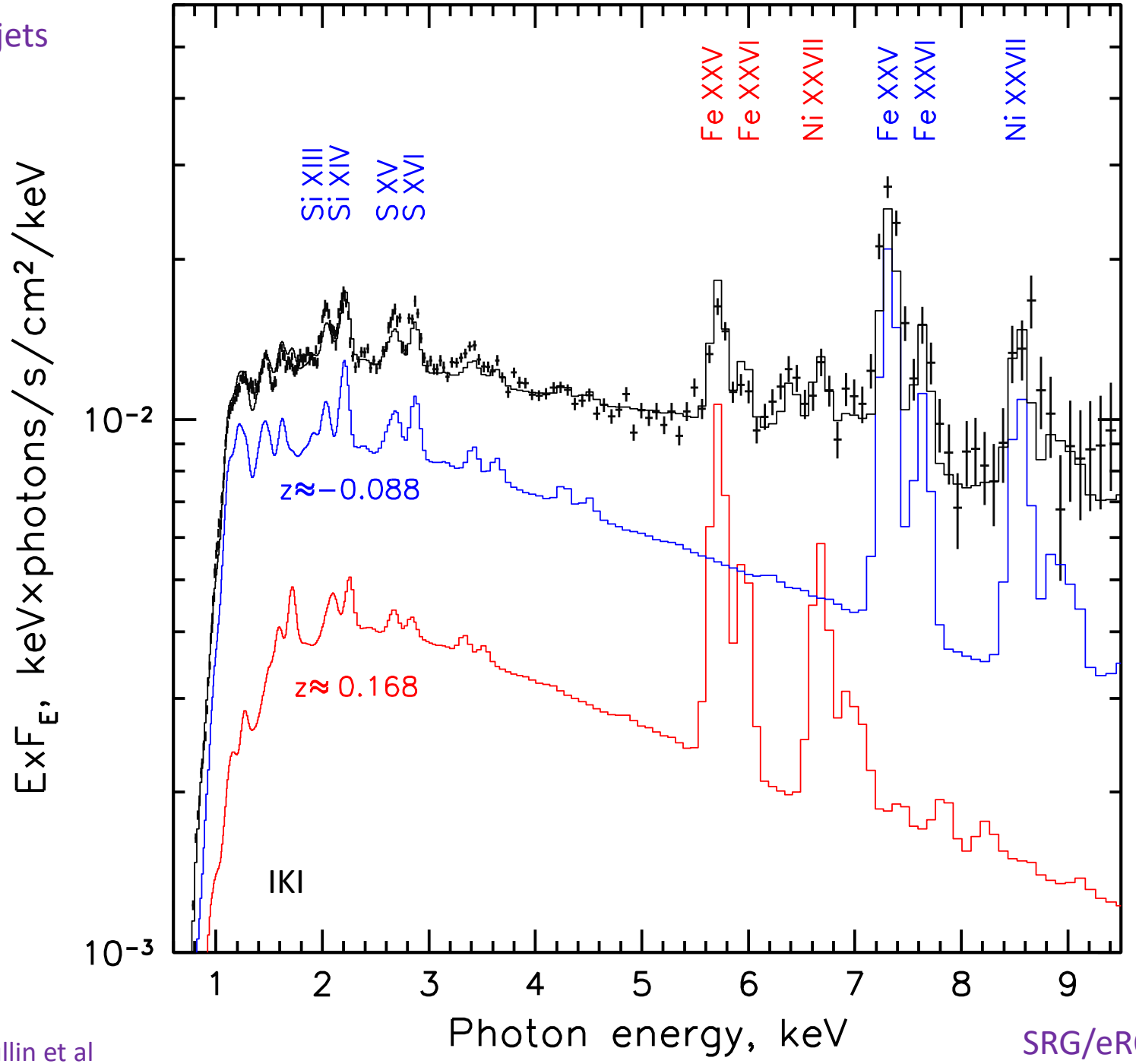


One revolution around direction toward Sun every 4 hours.

Every source on the sky is observed 6 times per day once in a half year (This permits to look for the short time variability)

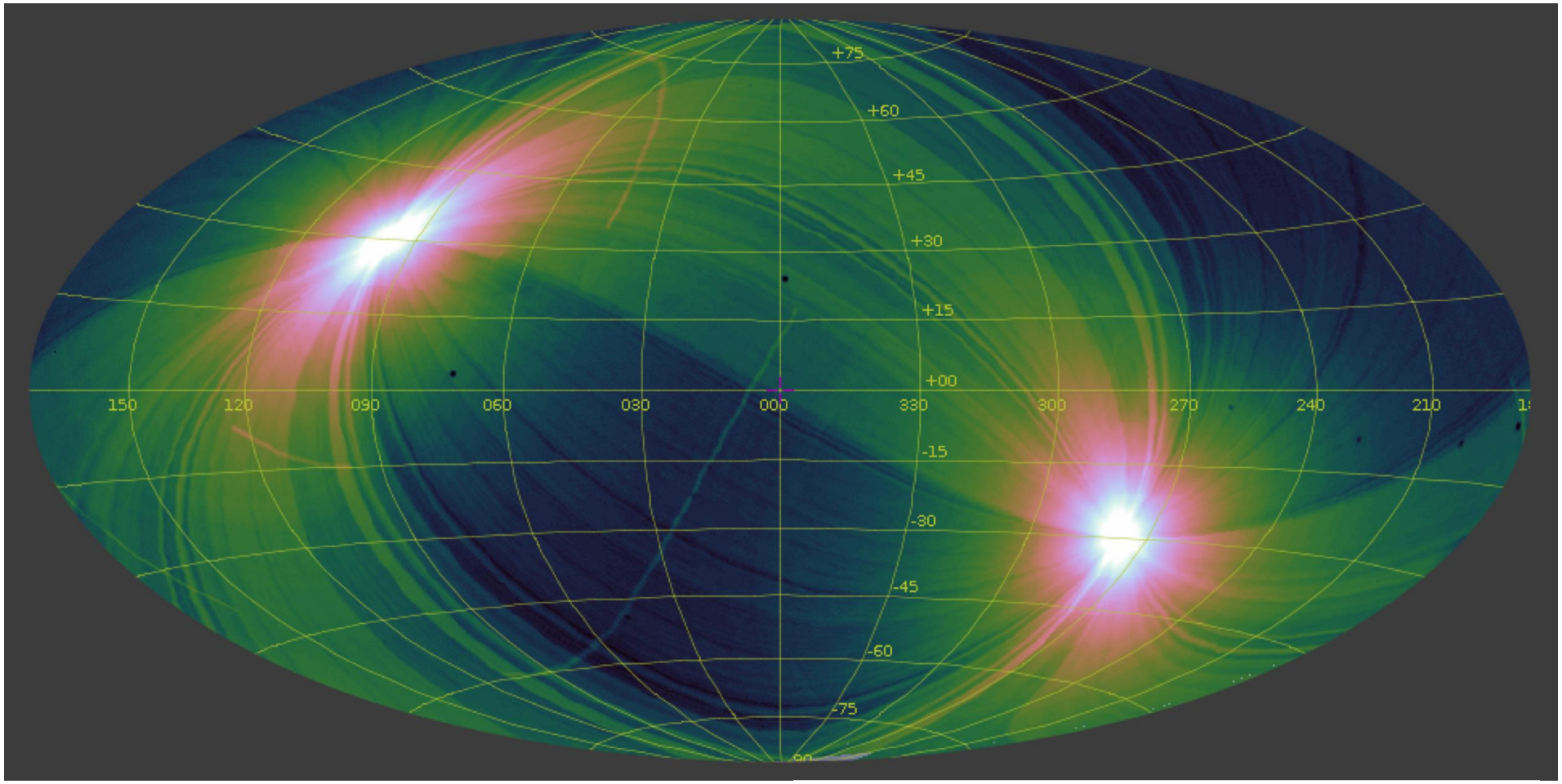

Lavochkin industry near Moscow
one of the clean rooms
SRG Observatory
total mass 2700 kg
eRosita (808 kg)
3.5m * 1.9m
Germany
ART-XC (350 kg)
Russia
Navigator
Platform

SS 433 jets



Khabibullin et al

SRG/eROSITA



Exposition map (galactic coordinates)

all individual scans intersect
in Ecliptic Poles