

# eROSITA

extended **RO**entgen **S**urvey with an **I**maging **T**elescope **A**rray

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**Cooling, Thermal Engineering:** M. Fürmetz + students

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**Attitude:** A. Schwobe

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**Laboratory, PUMA, Tests:** M. Vongehr, R. Gaida, K. Dittrich, F. Schrey

**Ground Software, Simulation:** H. Brunner, N. Cappelluti, G. Lamer, M. Mühlegger, J. Wilms, I. Kreykenbohm, Chr. Schmid

**Mission Planning:** J. Schmitt, J. Robrade

### Institutes:

**Max-Planck-Institut für extraterrestrische Physik, Garching/D**

Universität Erlangen-Nürnberg/D

Universität Tübingen/D

Universität Hamburg/D

Astrophysikalisches Institut Potsdam/D

Max-Planck-Institut für Astrophysik/D

Space Research Institute IKI, Moscow/Ru

Universität Bonn

Universität München (LMU)



### Industry:

Media Lario/I

Kayser-Threde/D

Carl Zeiss/D

Invent/D

pnSensor/D

EHP/B

RUAG/A

HPS/D,P

+ many small companies

Mirrors, Mandrels

Mirror Structures

ABRIXAS-Mandrels

Telescope Structure

CCDs

Heatpipes

Mechanisms

MLI

# eROSITA

extended ROentgen Survey with an Imaging Telescope Array

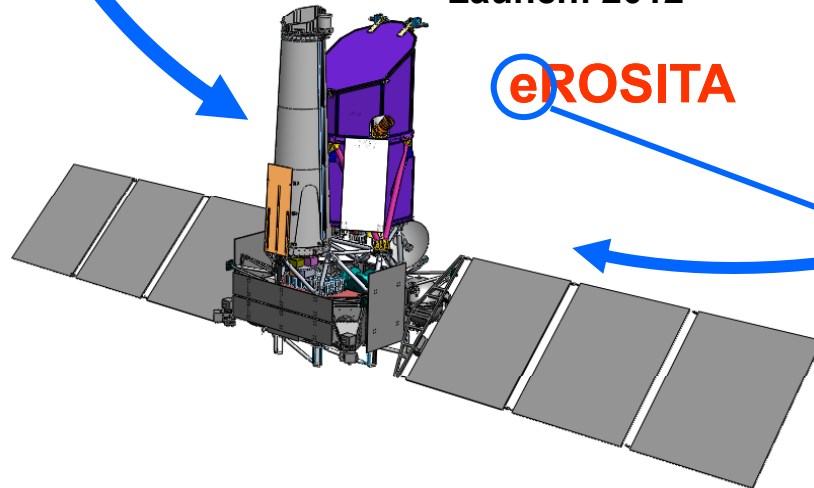
- History
- Design Driving Science
- Instrumental Concept
- Mission Scenario
- Science
- Mirrors
- Status

# Historical Development



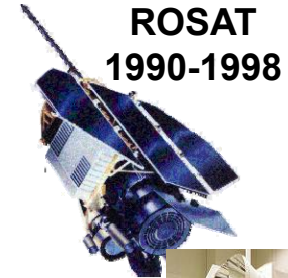
Negotiations between Roskosmos and ESA  
on a "new" Spectrum-XG mission (2005)

MoU between Roskosmos and DLR (2007)



eROSITA

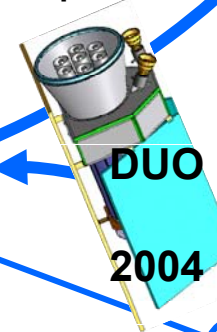
First X-ray all-sky survey  
with an imaging telescope



Bundle of 7 small telescopes  
To extend the all-sky survey  
towards higher energies

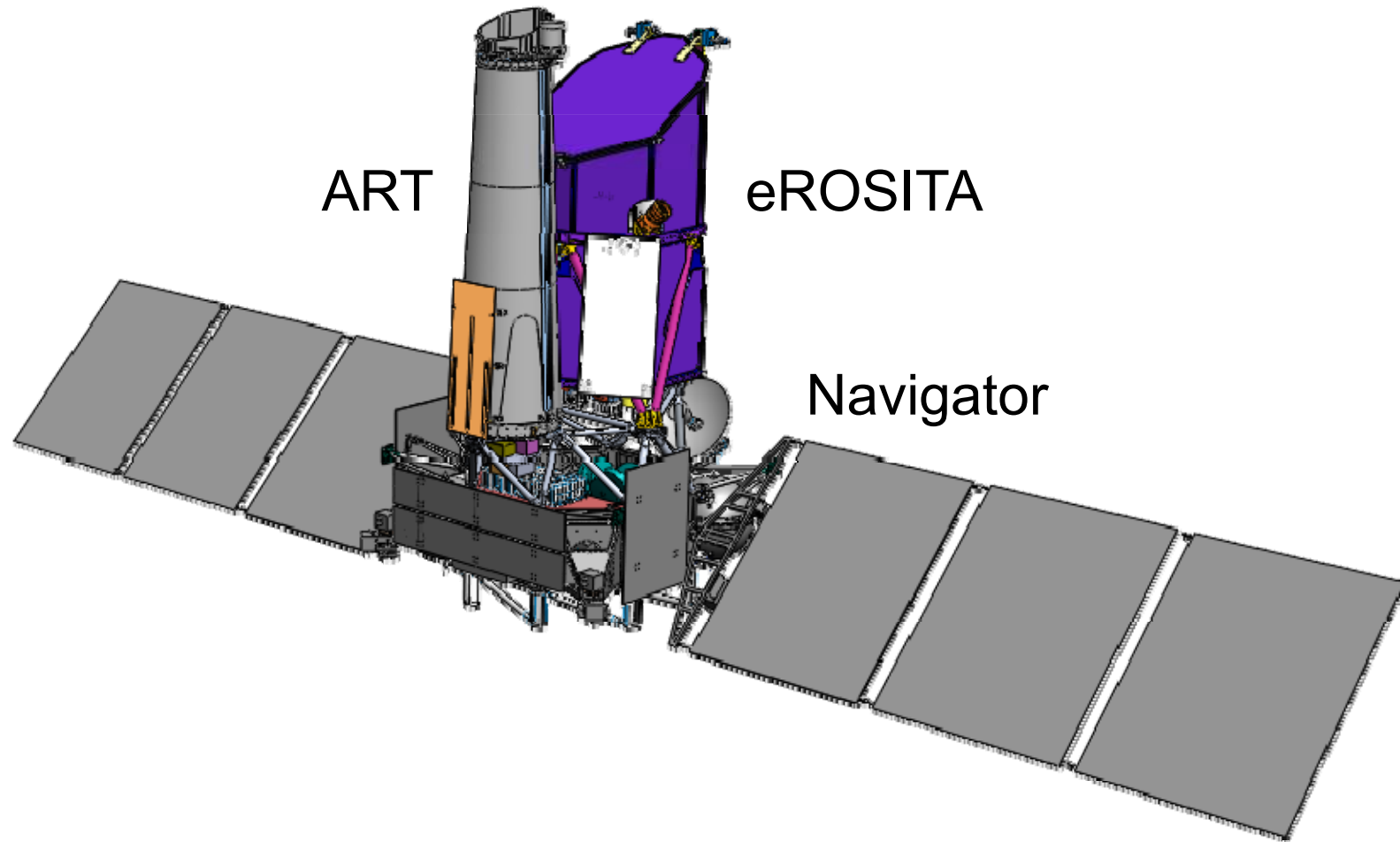


ABRIXAS science on the  
International Space Station

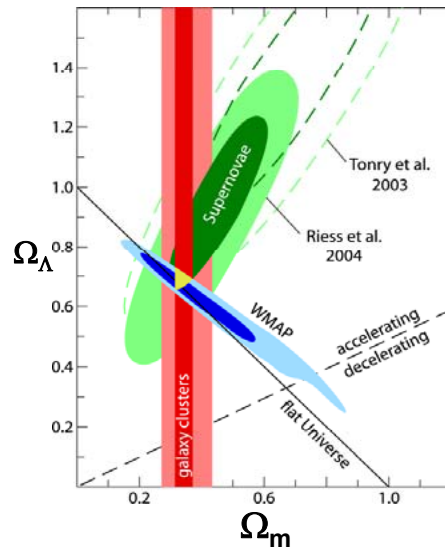


Dark Energy  
 $10^5$  Clusters of Galaxies

# *Spektrum-Roentgen-Gamma*

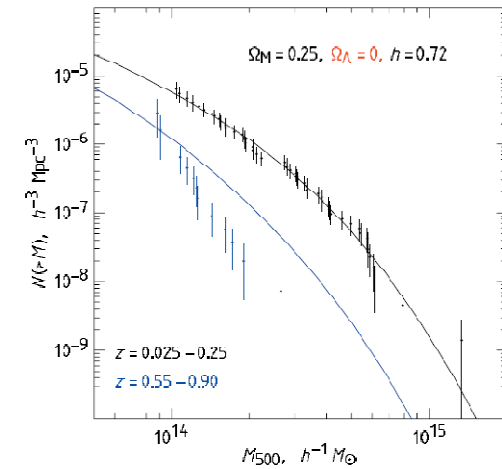
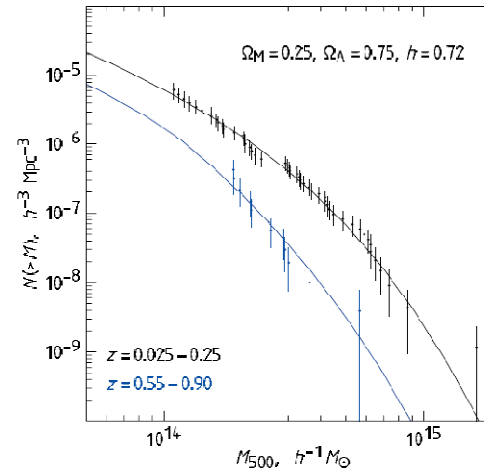


# Observational Constraints



WMAP results from Spergel et al. 2003

REFLEX results from Schuecker et al. 2003

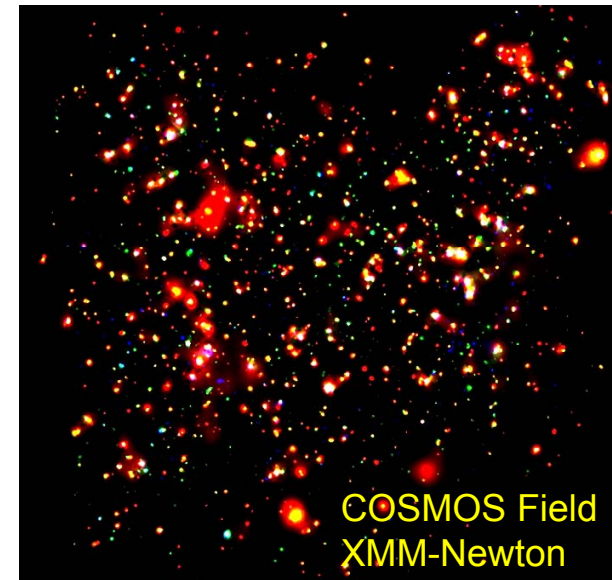


Vikhlinin et al., 2009

- WMAP → Flat Universe
- SN Ia → Accelerated Expansion
- Clusters → Matter density

Clusters of galaxies are the largest gravitationally bound entities in the universe

In X-rays we see clusters as one continuous entity



# *Design Driving Science*

- Constrain parameters of Dark Energy



- Detectability of 100.000 Clusters of Galaxies,  $z < 1.5$ 
  - All-sky survey with sensitivity  $6 \times 10^{-14}$  erg cm<sup>-2</sup> s<sup>-1</sup>
  - Deep survey field(s) ( $\sim 100$  sqdeg) with  $1 \times 10^{-14}$  erg cm<sup>-2</sup> s<sup>-1</sup>
  - Individual pointed observations



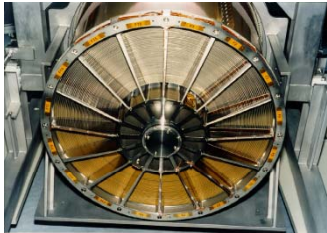
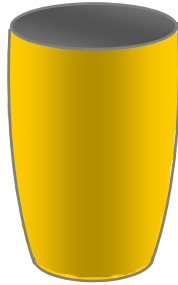
- Instrument:
  - Moderate angular resolution ( $< 28$  arcsec, aver. over FoV)
  - Large collecting area ( $> 2000$  cm<sup>2</sup> @ 1keV)
  - Large FoV ( $1^\circ \text{ } \emptyset$ )
  - Long duration (survey 4 years  $\leftarrow \rightarrow$  1/2 year (ROSAT))

# *Galaxy Clusters known today*

- ~ 200 – 300 from Einstein (1978 – 1981)
- ~ 1000 published from ROSAT (1990 -1998)
- ~ 1000 to be published from reanalysis of ROSAT data
- ~200 – 300 from XMM-Newton archival data
- + 10 – 15 with redshift  $> 1$

# Historical Development

**XMM**



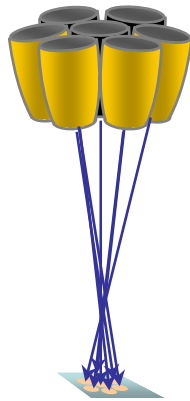
**2000 cm<sup>2</sup>  
58 Shells  
f = 750 cm**



**6x6 cm<sup>2</sup> pnCCD**

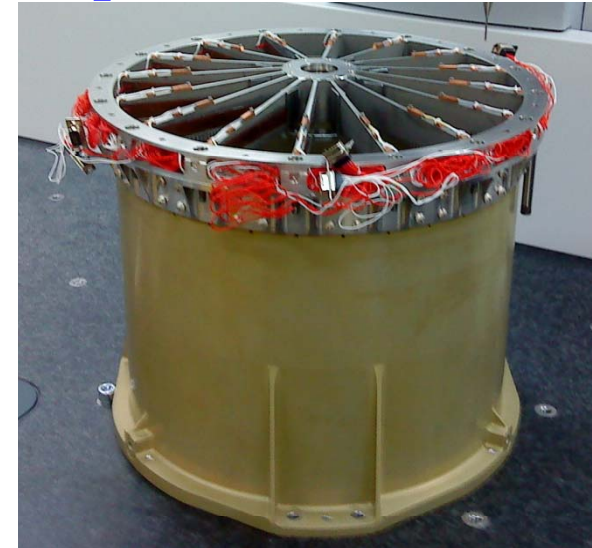


**ABRIXAS**

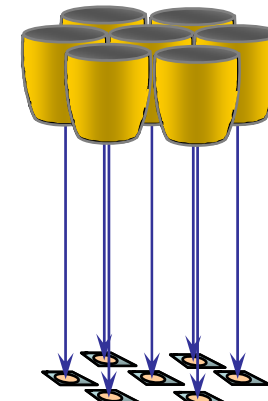


**7 x 70 cm<sup>2</sup>  
27 Shells  
f = 160 cm**

**7 3x3 cm<sup>2</sup> pnCCD-framestore**



**eROSITA**



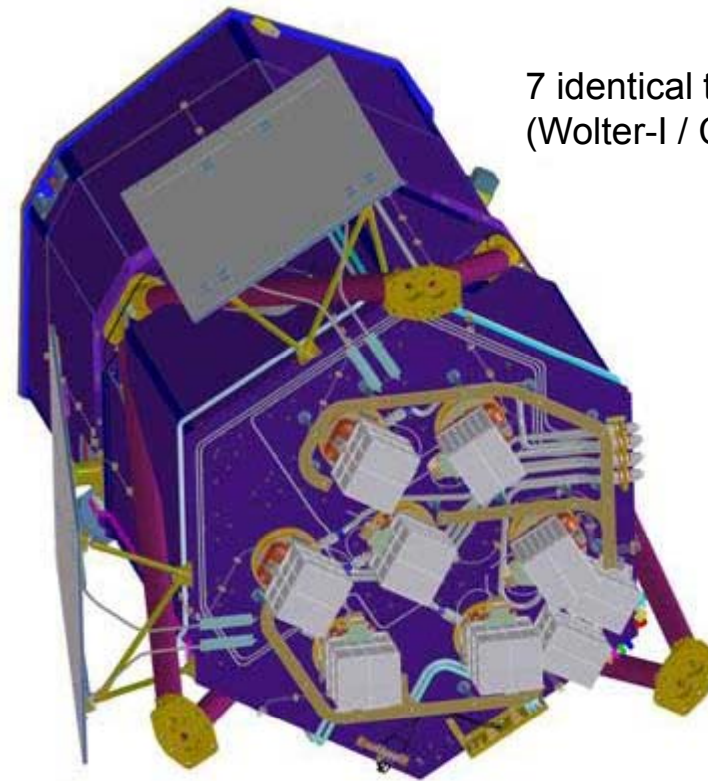
**7 x 350 cm<sup>2</sup>  
54 Shells  
f = 160 cm**



# eROSITA Telescope



3265 mm w/o Cover

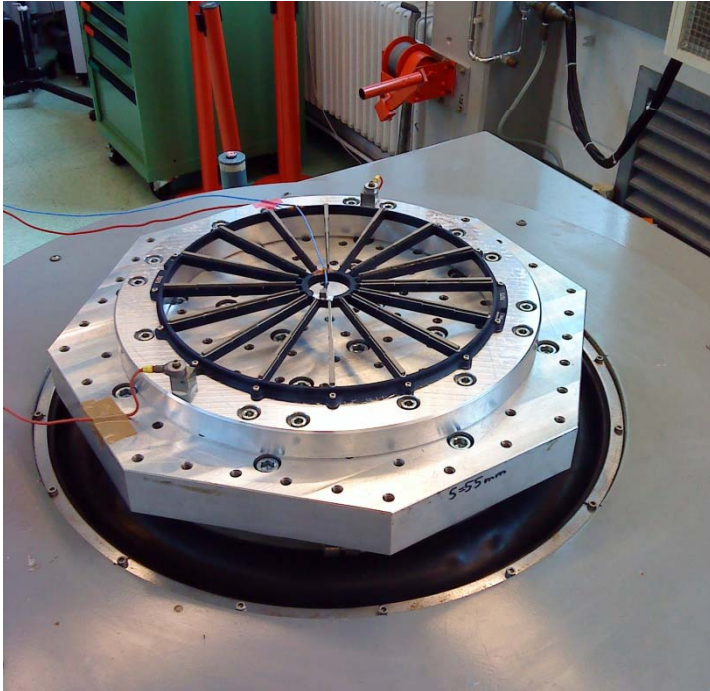


7 identical telescopes  
(Wolter-I / CCD-camera)

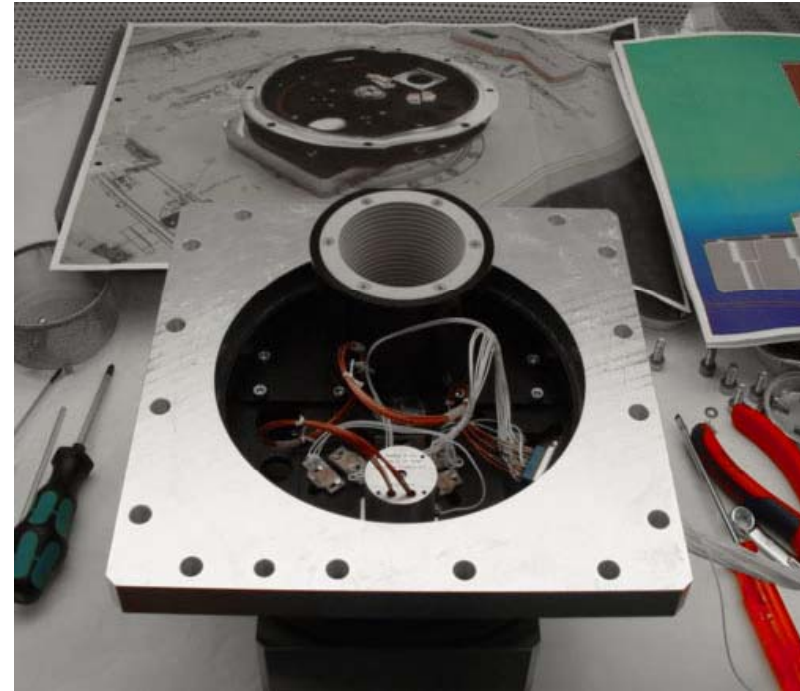
1941 mm

The FM-structure will be delivered to MPE in Oct. 2010  
Integration will start in Nov. 2010

# *Hardware Development*

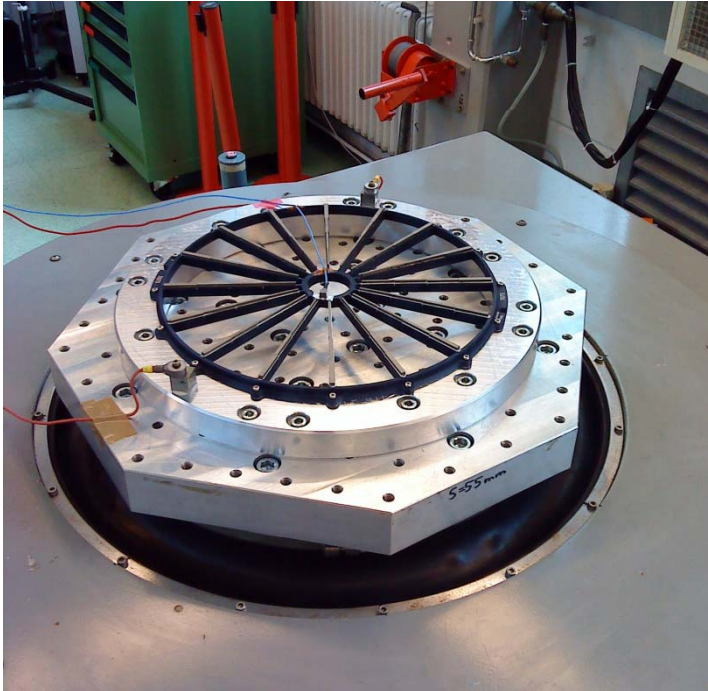


Electron Deflector  
on shaker at MPE

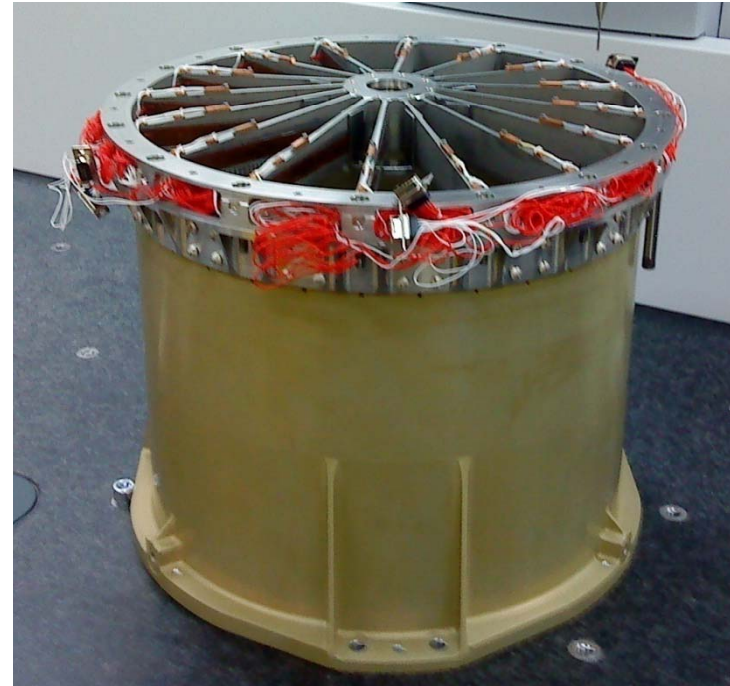


Filter Wheel  
in preparation  
for qualification tests

# *Hardware Development*



Electron Deflector  
vibrational test



Mirror Module

# *Hardware Development*

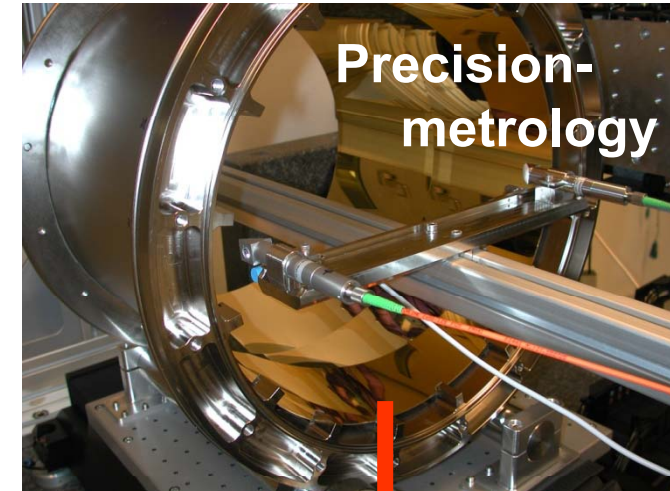


Structural Model on Shaker

Mirror Spider Wheel



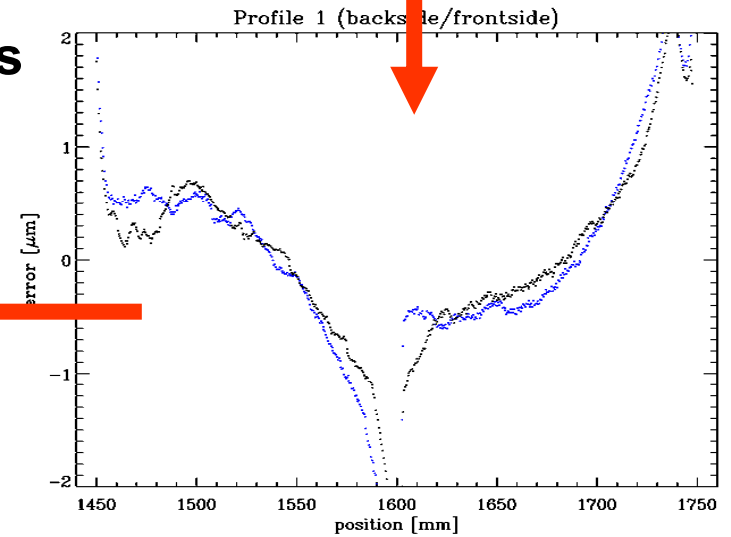
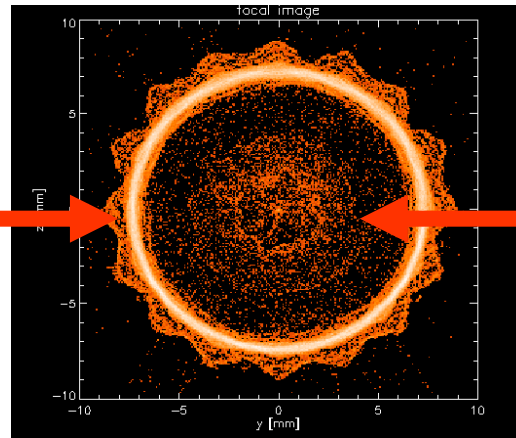
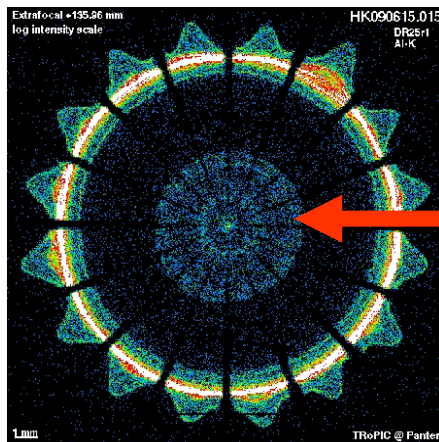
# Laboratories



**X-ray measurements**

**Profile Errors**

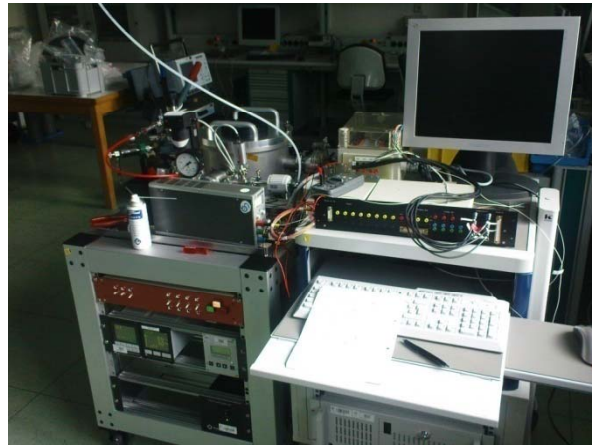
**Raytracing - Analysis**



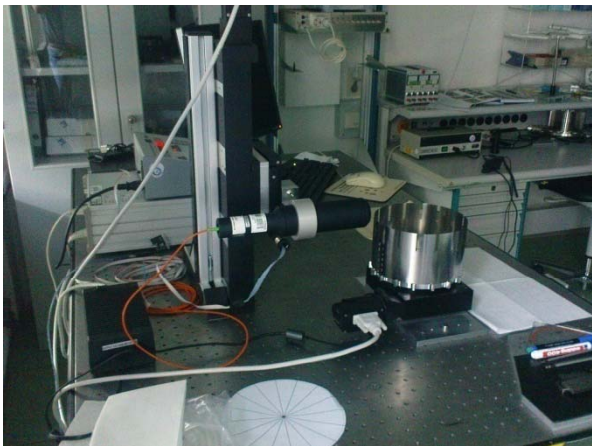
# Laboratories



electron deflector test at PUMA



cryogenics



X-ray baffle metrology

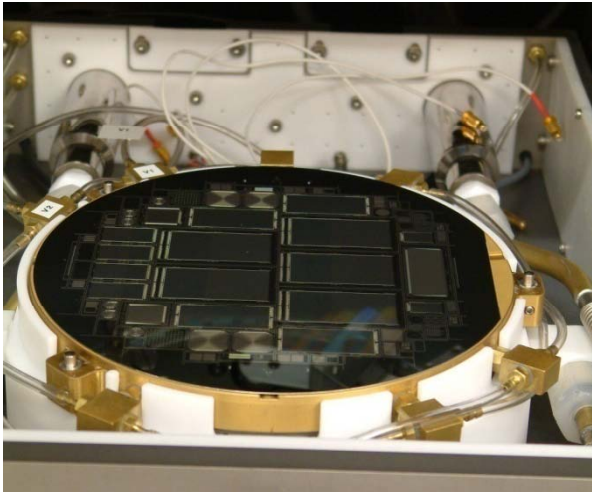


glue shrinkage tests

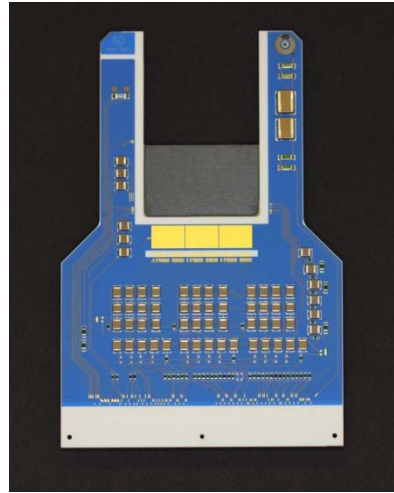


mirror shell  
screening device

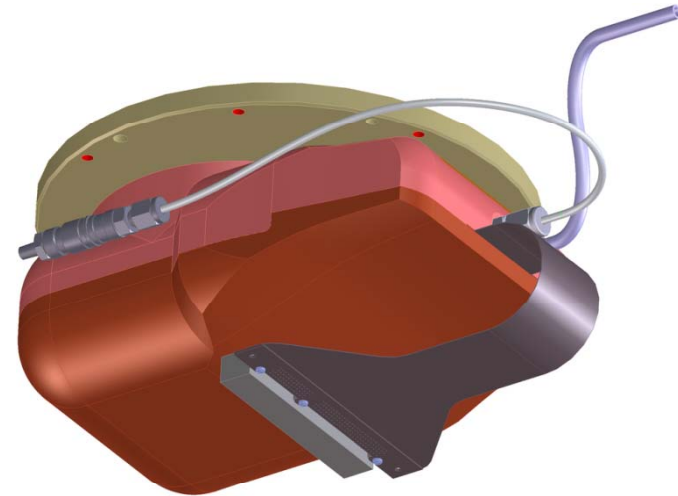
# CCD - Camera



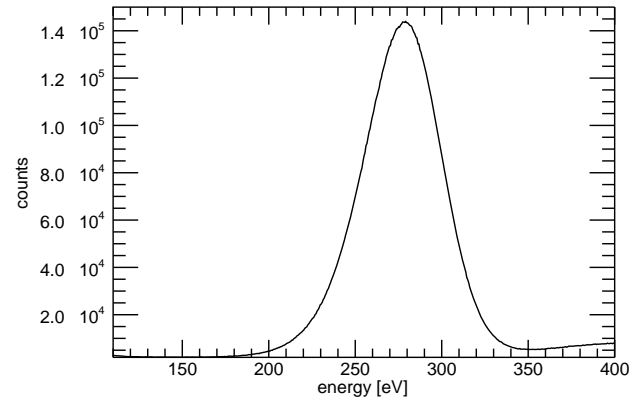
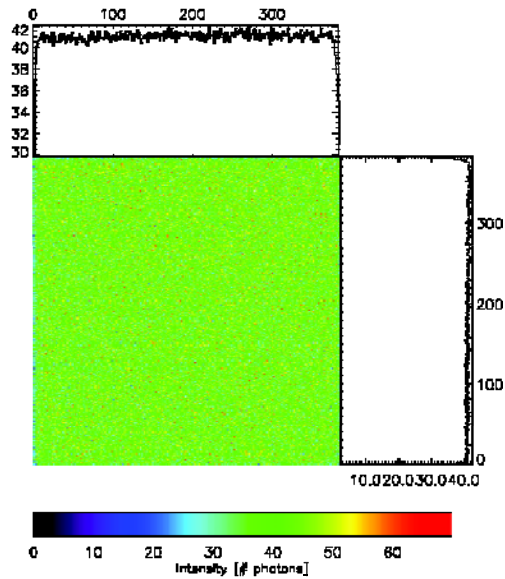
pn-CCDs on wafer in test



front-end ceramics



camera housing



performance (flat field, E-resolution)

# Instrument Parameters

Focal length	1600 mm
Diameter	360 mm
# of shells	54
HEW on-axis	15"
HEW averaged	28"

eROSITA total	735 kg
single Mirror Module	48 kg
single Camera	20 kg
Telescope Structure	148 kg
Electronics total	37 kg

Size	28mm x 28mm
FoV	61 arcmin $\varnothing$
Pixelsize	75 $\mu$ m
integ. time	50 msec
energy resol.	140 eV @ 6 keV

Power total	352 W
Single Camera	24 W
Electronics	
Controller	24 W
Thermal	140 W

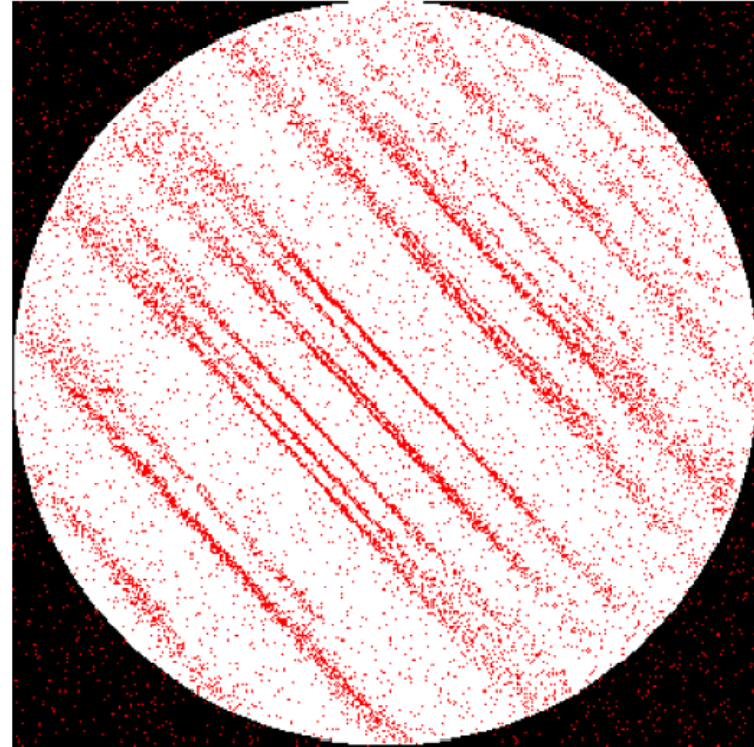
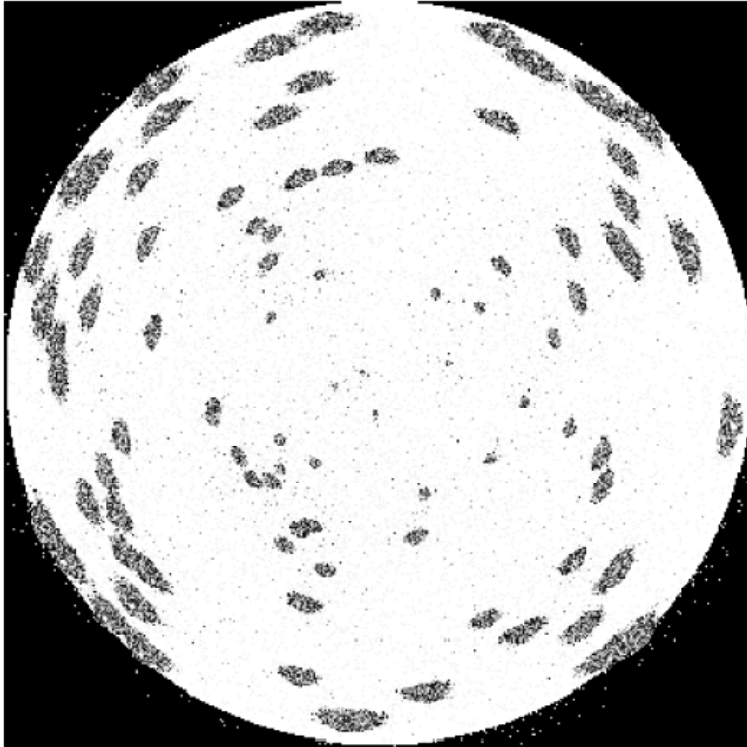
eff. area	2300 cm <sup>2</sup> (1keV) 500 cm <sup>2</sup> (5 keV)
Grasp	700 cm <sup>2</sup> deg <sup>2</sup> (1keV)
Sensitiv.	6 $\times$ 10 <sup>-14</sup> cluster, all-sky 1 $\times$ 10 <sup>-14</sup> cluster, deep 1 $\times$ 10 <sup>-14</sup> point-s, all-sky 3 $\times$ 10 <sup>-15</sup> point-s, deep

Length (launch config)	3,3m
Length (orbit conf.)	4,7m
Diameter	1,9m



# eROSITA Simulations

by Chr. Schmid



## Pointing

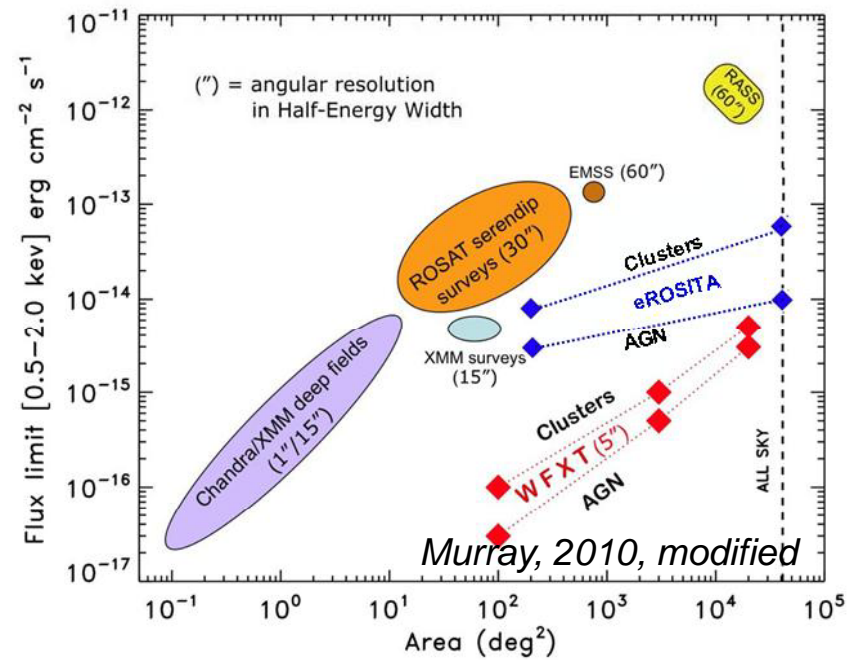
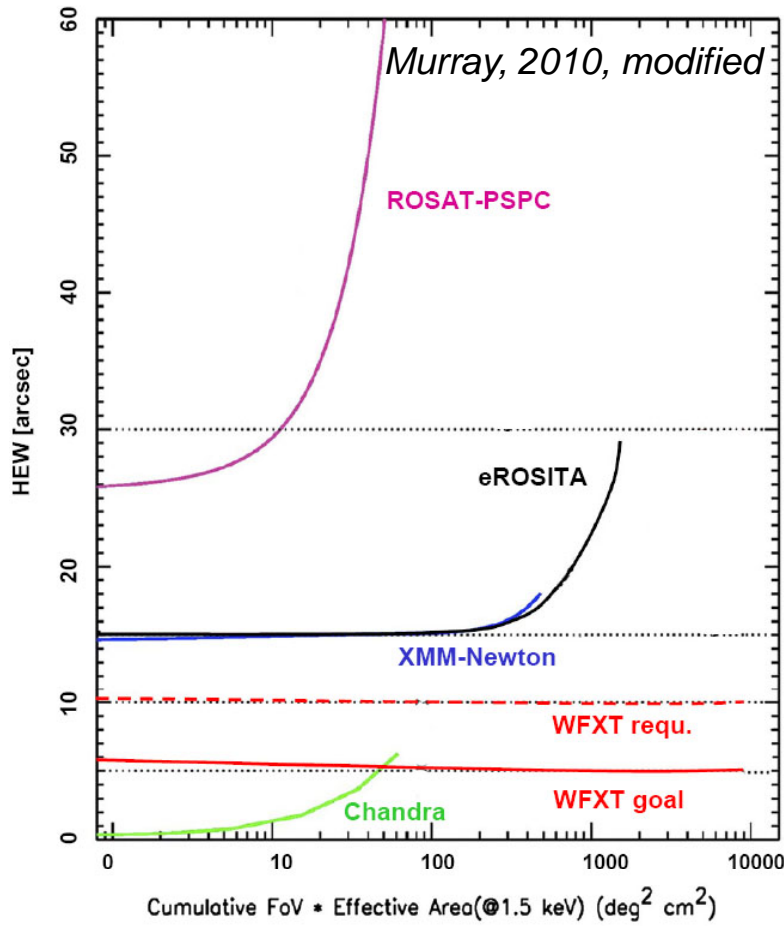
Off-axis blurring of a Wolter-I telescope →

PSF has to be averaged over the FoV

15 arcsec on-axis → 28 arcsec averaged

## Survey

# Grasp and Sensitivity



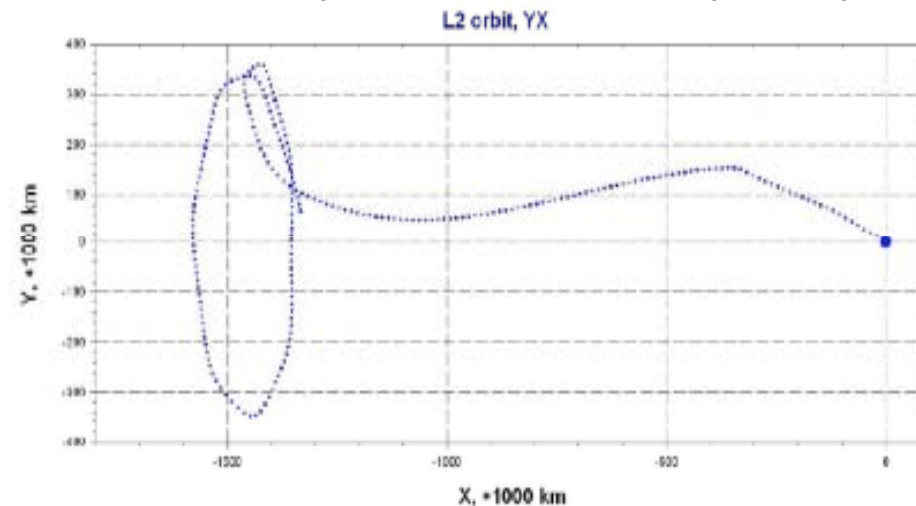
eROSITA-Expectation:

- 100,000 clusters
- 3 Million AGN

# Mission Plan



- **3 Months:** flight to L2, verification and calibration phase
- **4 years:** All sky surveys (8 scans)
- **~3.5 years:** pointed observation phase, including ~20% of GTO (gaps, cluster followup, etc.). 1 AO per year
- **ToO** will be possible only in exceptional cases
- Sky will be divided into two hemispheres
- German (MPE) half: proprietary period TBD (likely 2 yrs)
- Public Release of 8 all-sky scan data every 1/2 year



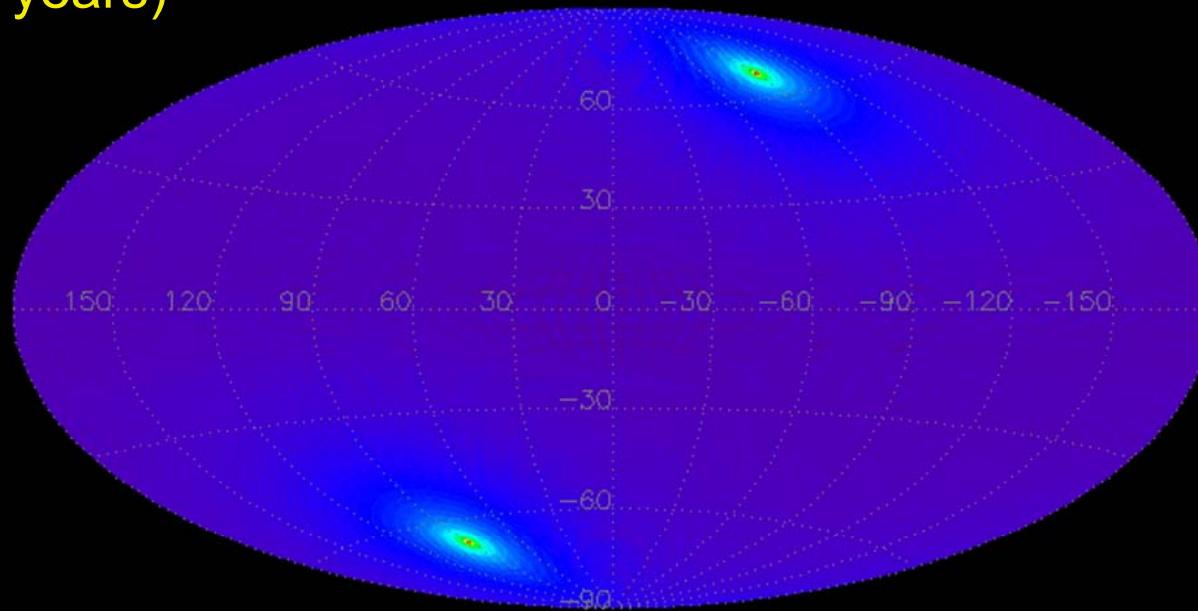
Launcher: Zenith-Fregat

V. E

#6, Frascati, 12-04-2011

# ***Key feature needed: AREA***

eROSITA is an instrument designed to perform all sky 0.5-10 keV surveys:  
**LARGE FOV (0.81 deg<sup>2</sup>), large effective area, good resolution (25-30"), long life (7.5 years)**

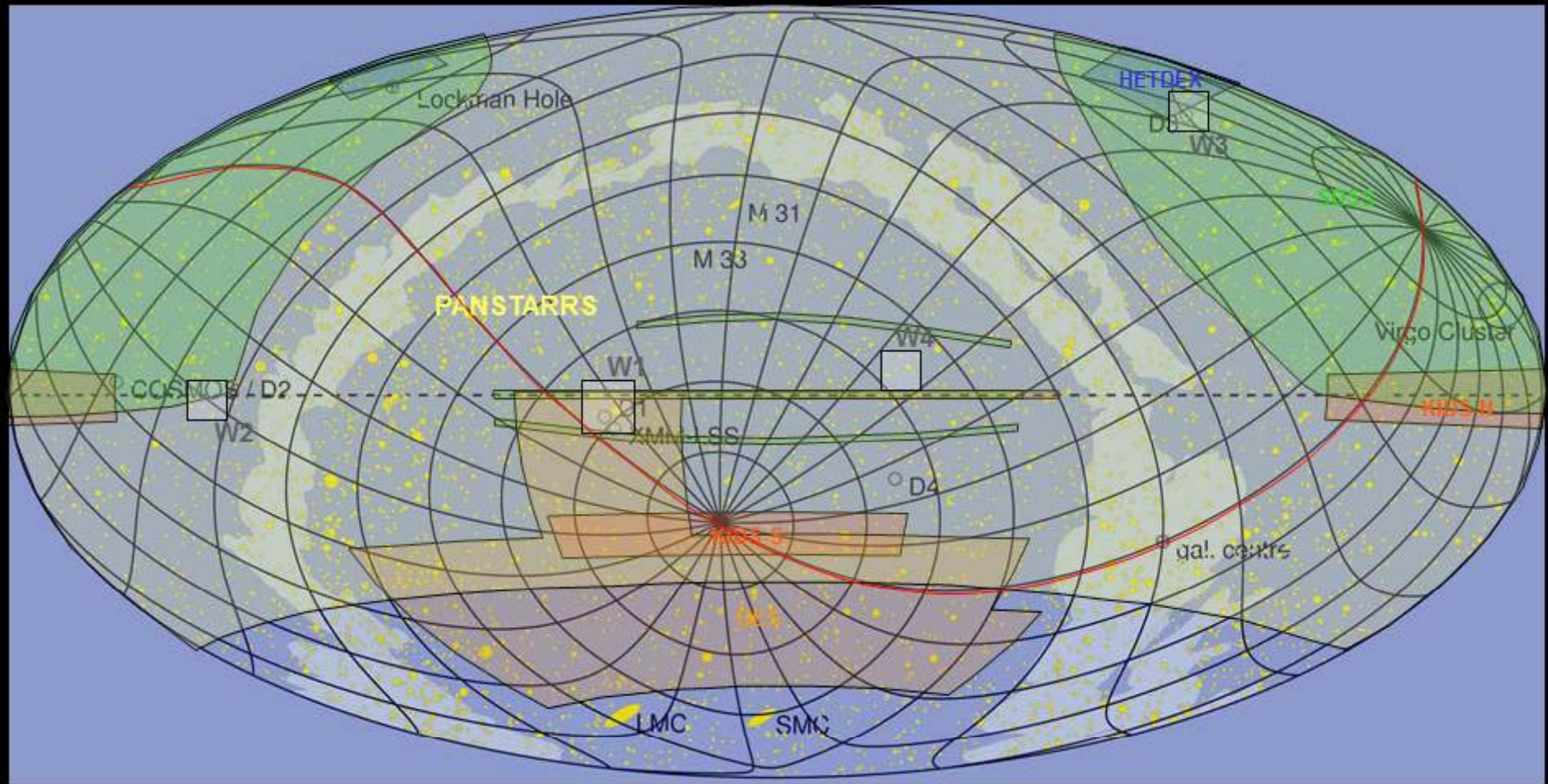


1.5 5.0 25 300 ksec

Area covered at ~20 ks is  
~125 deg<sup>2</sup>

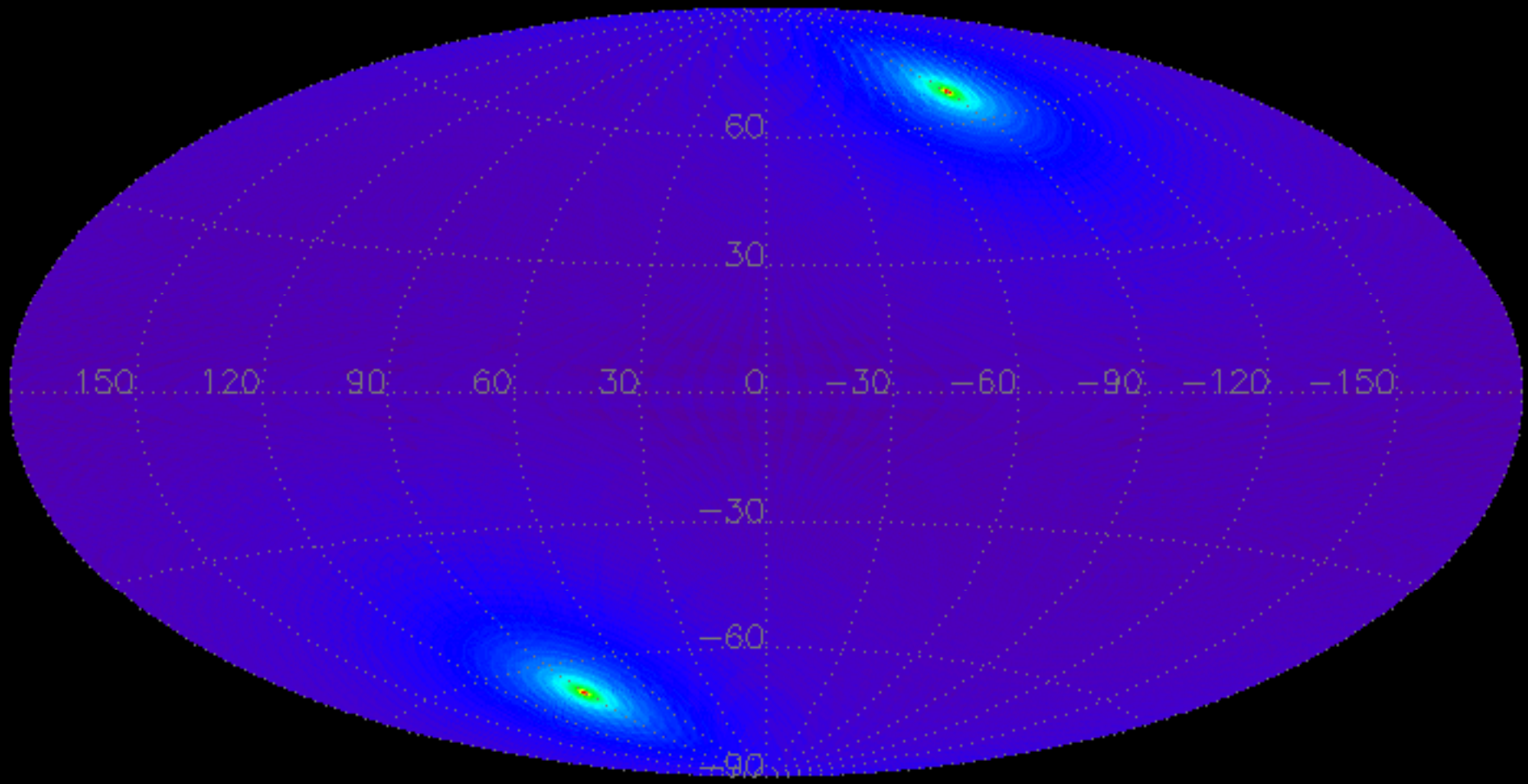
(M. Fürmetz, MPE)

# *Sky (german/russian) division*



(P. Friedrich, MPE)

# *Sky (german/russian) division*

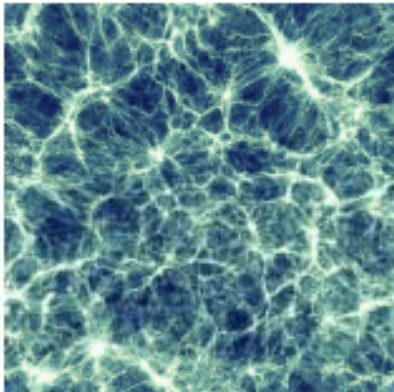


(P. Friedrich, MPE)

# eROSITA Simulations

M. Mühlegger, 2010

Cosmological hydrodynamical simulation



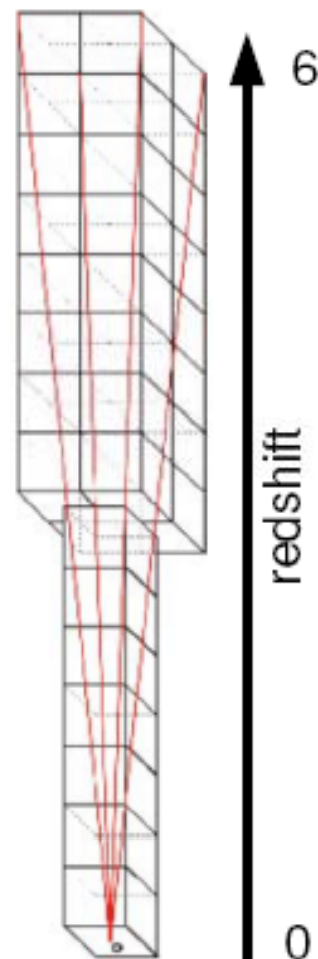
Borgani et al. 2004

192 Mpc/h Box size

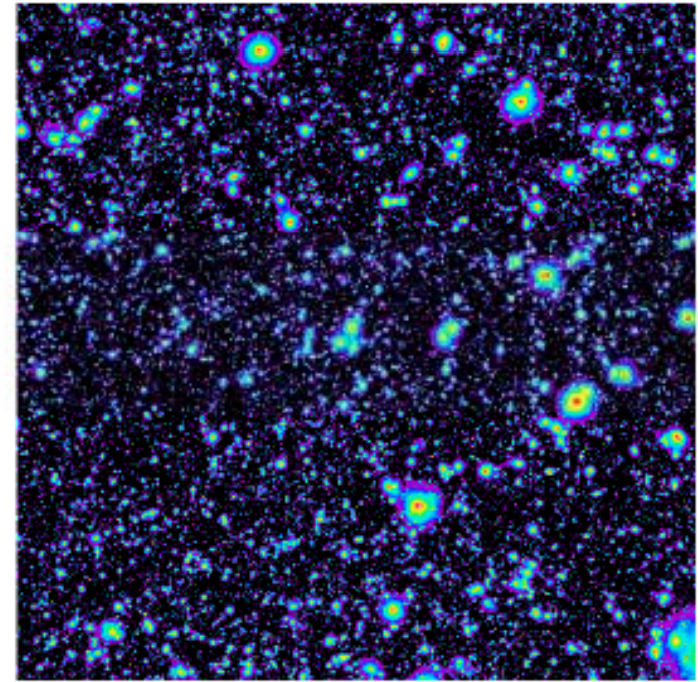
$480^3$  DM particles (a  $6.6e+9 M_{\text{sol}}$ )

+  $480^3$  gas particles (a  $9.9e+8 M_{\text{sol}}$ )

light-cone



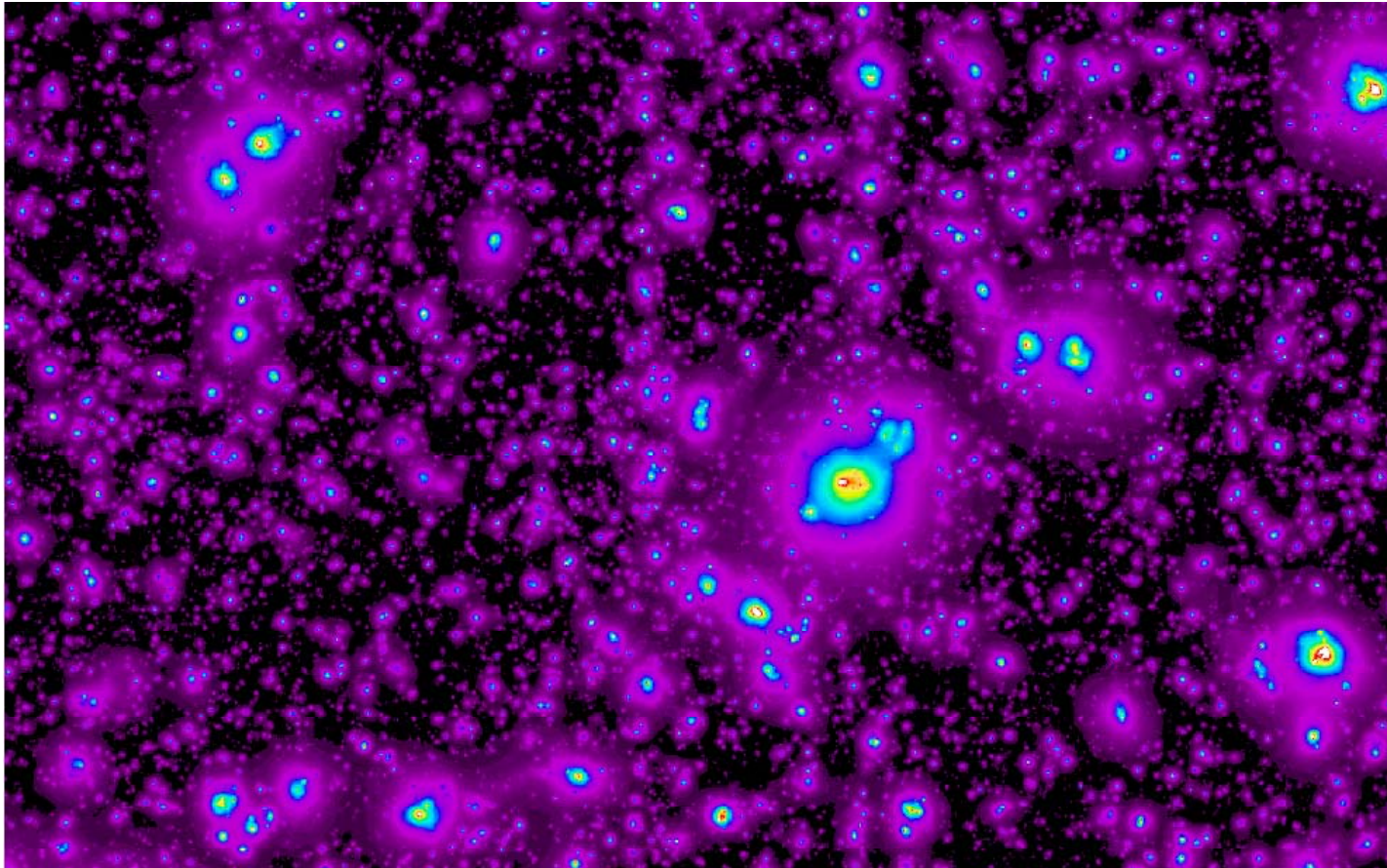
Surface brightness map  
[erg/s/cm<sup>2</sup>/deg<sup>2</sup>] (3.77deg)<sup>2</sup>



Mass range:  $1e11 .. 6e14 M_{\text{sol}}$

# *eROSITA Simulations*

*M. Mühlegger, 2010*

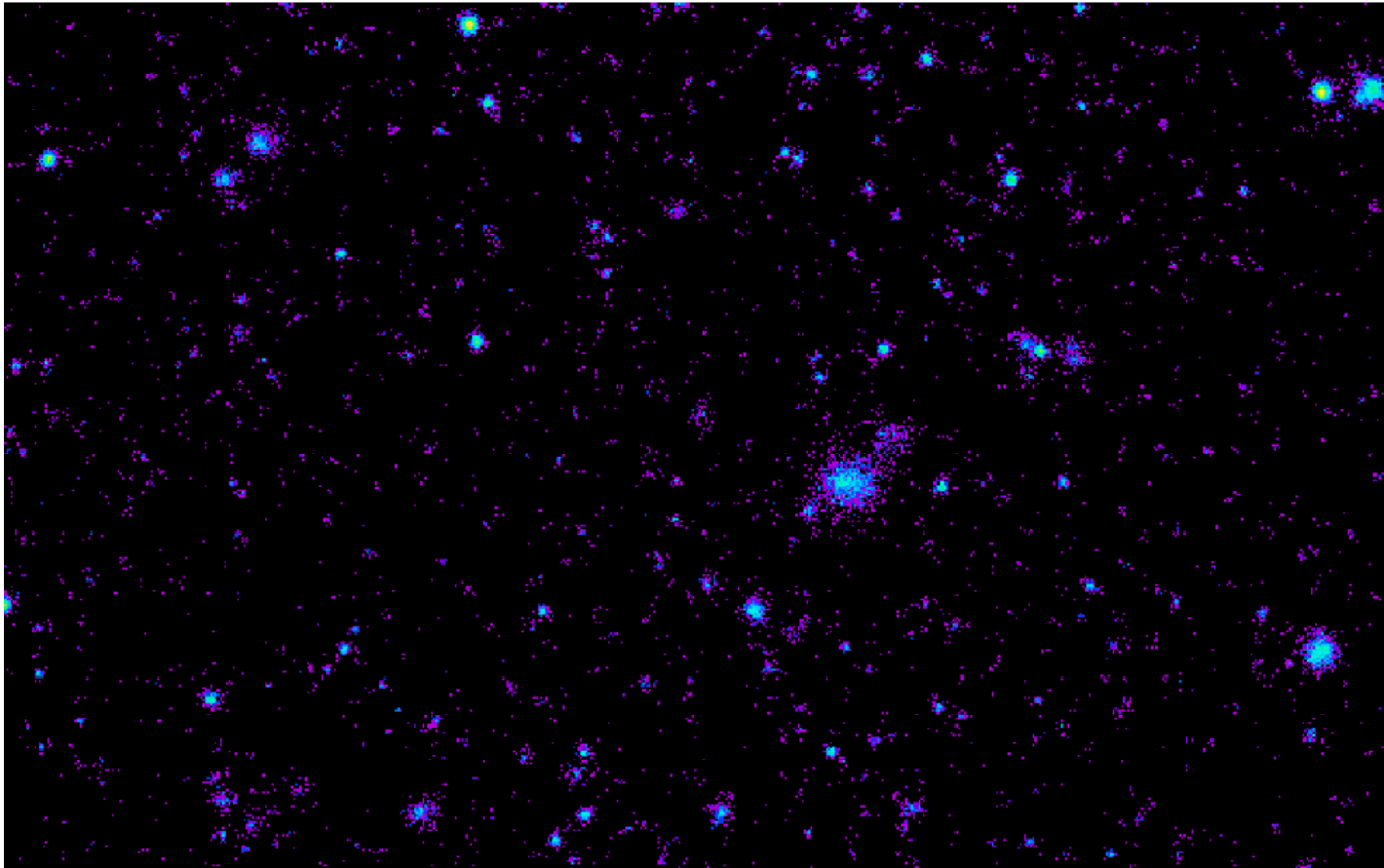


Surface brightness map ( $1^\circ \times 1,6^\circ$ )



# *eROSITA Simulations*

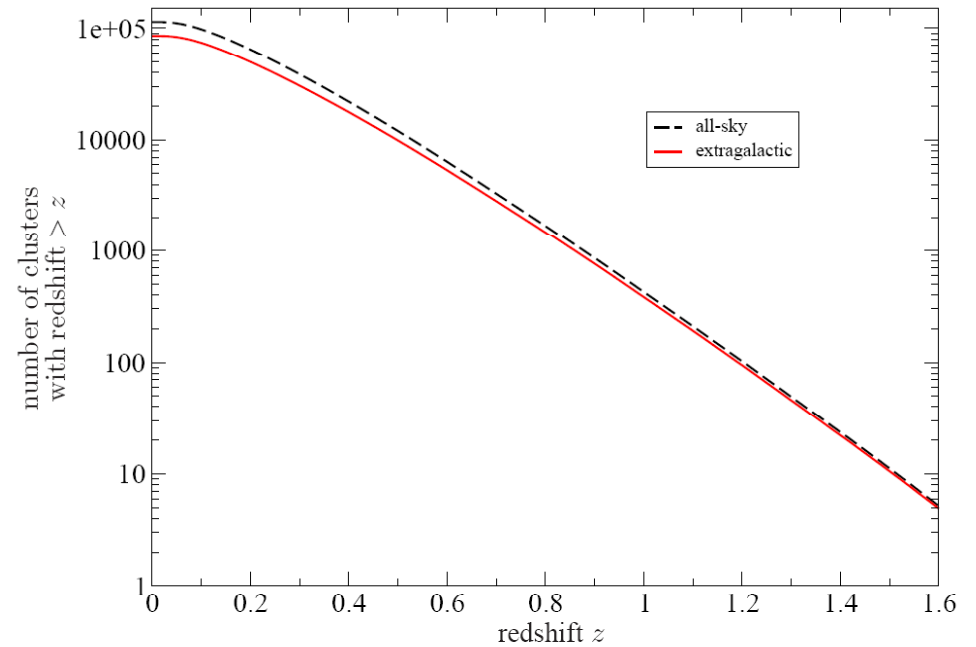
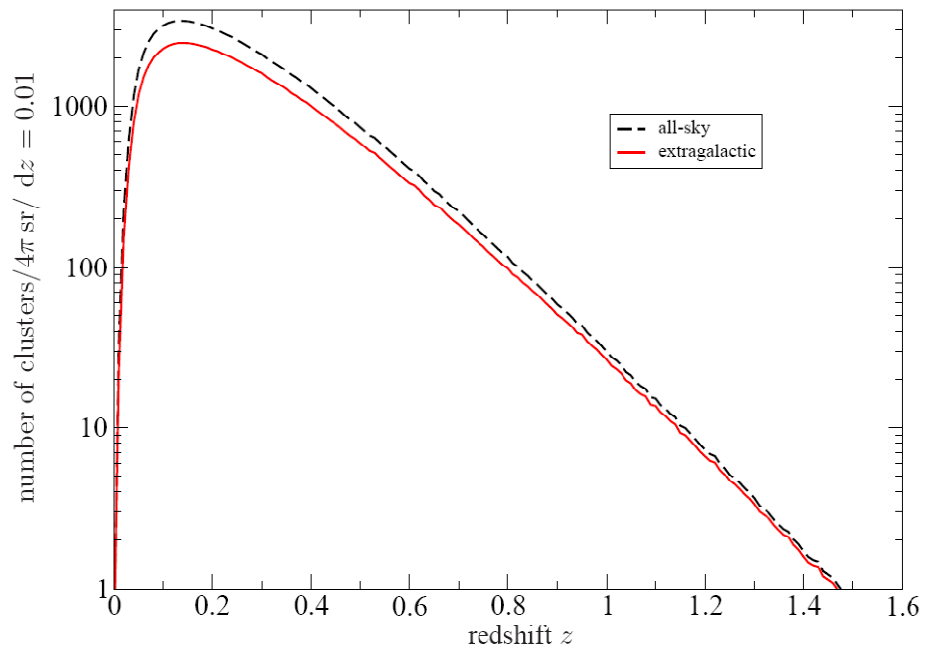
*M. Mühlegger, 2010*



Same region,  $A_{\text{GN}} + B_{\text{KGR}} + C_{\text{Clusters}}$ , 3ks, PSF convolved

# Expected number of clusters

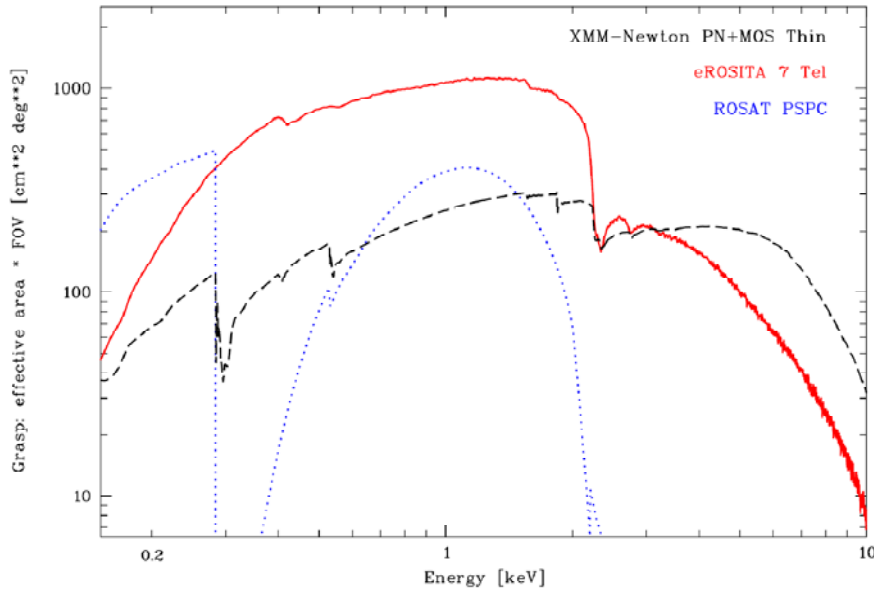
M. Mühlegger, 2010



100 cts for detection

# eROSITA Sensitivity

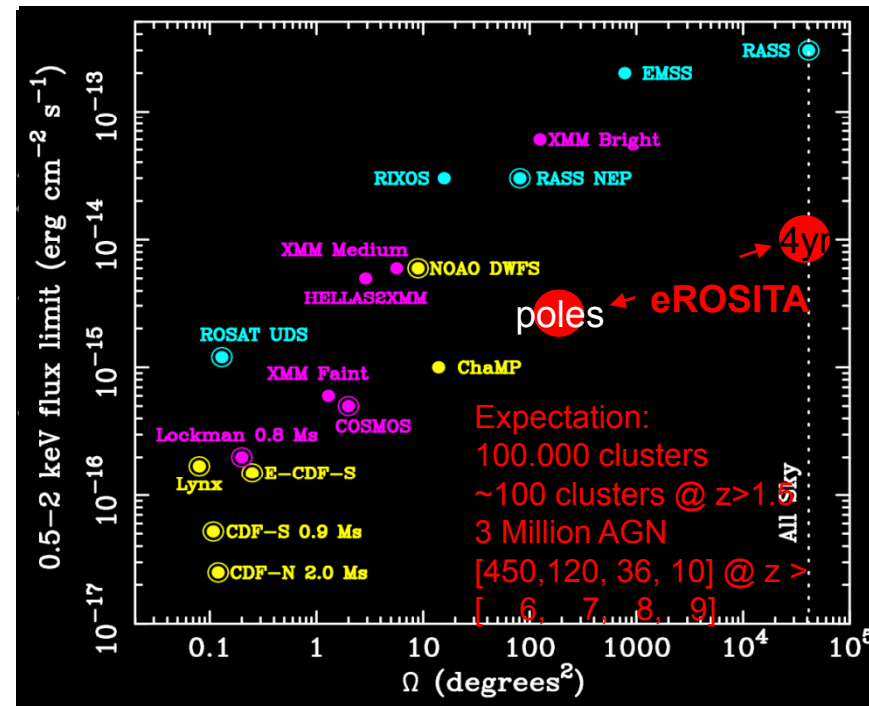
## Grasp



7 telescopes, 350  $\text{cm}^2$  each  
large field of view (61 arcmin  $\varnothing$ )

~ 2 × XMM-Newton (MOS+PN)

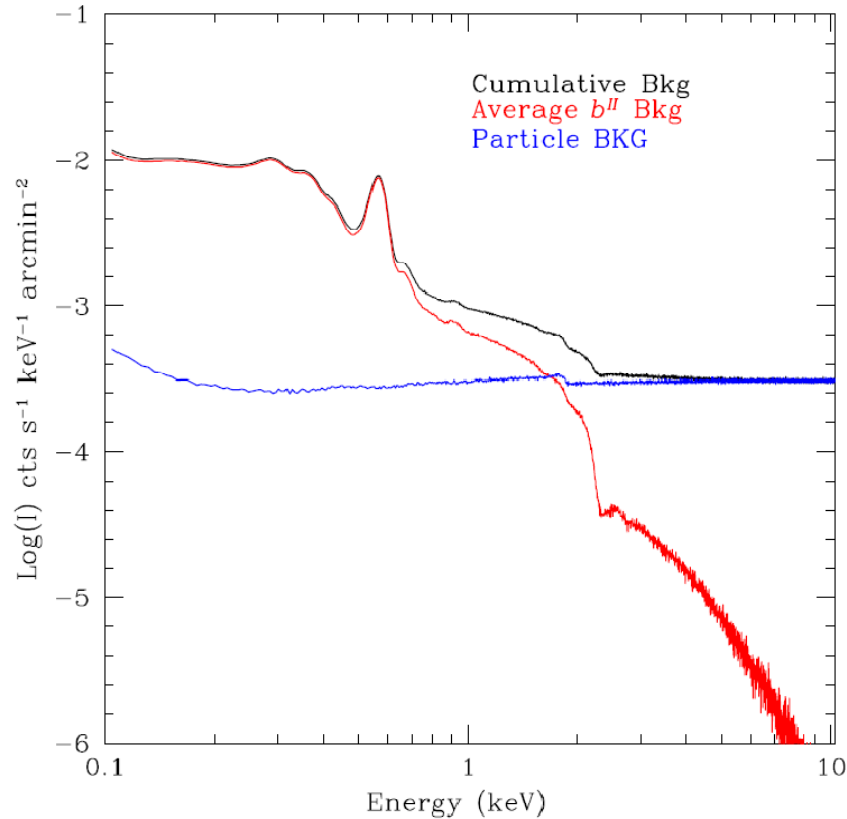
## F- $\Omega$



for point sources

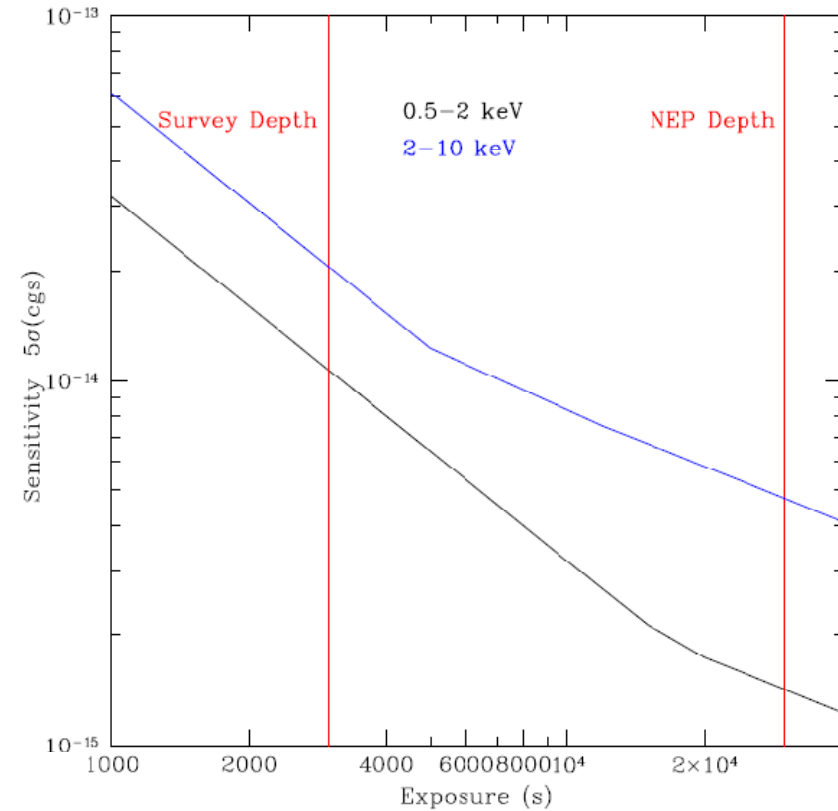
# Background and Sensitivity

N. Cappelluti, 2010



Soft background dominated by galactic/cosmic component.

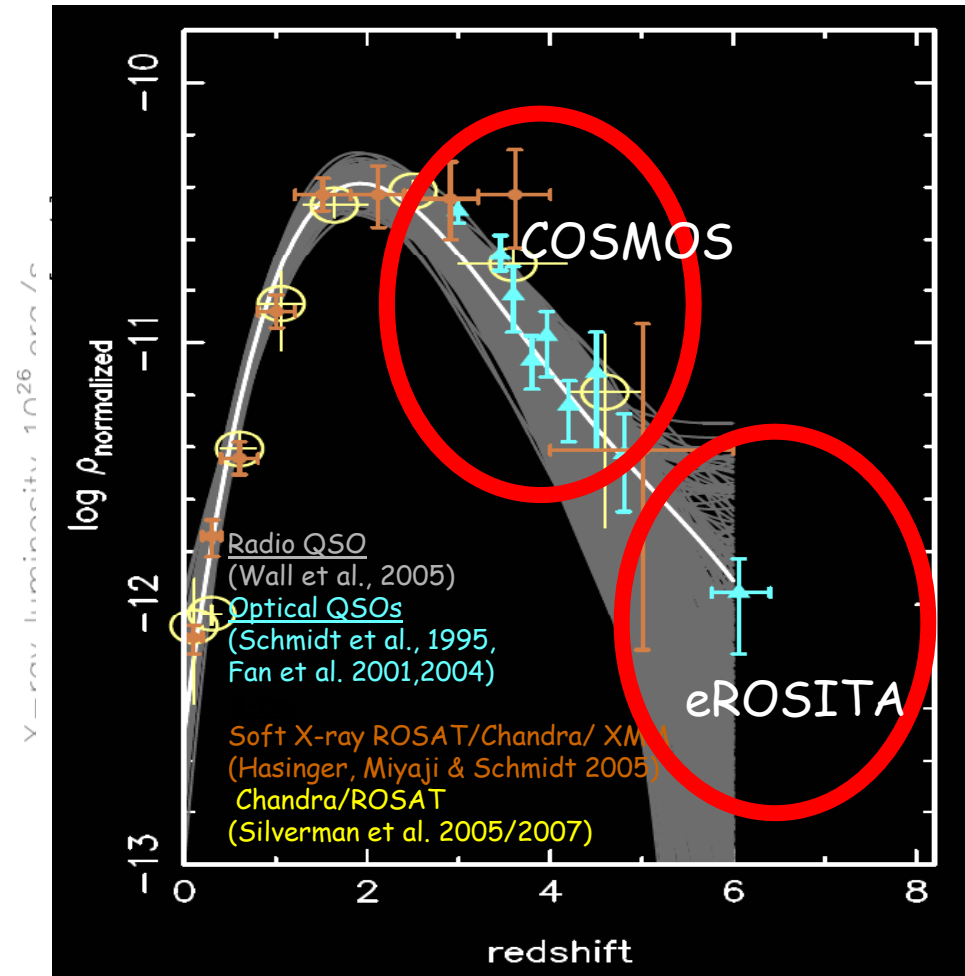
Hard X-ray background dominated by charged particles background.



Survey data photon limited both in the soft and hard X-ray background. Sensitivity at the poles similar to that of XMM-COSMOS

# Lots of Science...

- AGN evolution
- Time resolved accretion physics (*variabilities hours - years*)
- Stellar variability on different time scales: hours to years
- Interstellar Medium (spectroscopy, dust scattering etc.)
- GRB afterglows (~50)
- CVs, XBs, Isolated Neutron Stars, SNRs etc.



# *Follow-up Observations*

- The X-ray spectrum can consistently provide the redshift only for a minority of the sources ( $\sim 3\%$  at most).
- Substantial optical/near-IR follow-up (or companion surveys) required.
- Accurate redshifts ( $dz \sim 0.02$ ) to  $z < 1.5$  for  $> 100,000$  clusters from multi-band photometry, covering wavelength of  $< 1\mu\text{m}$  for clusters at  $z=1.5$ , deep enough to obtain  $\sim 10$  cluster members.
  
- The Sloan Digital Sky Survey (SDSS) provides spectroscopic redshifts of cluster galaxies to  $z \sim 0.6$  over  $\sim 7000 \text{ deg}^2$ .
- CFHT/MegaCam provides photo- $z$ 's (u,g,r,i,z, depth=25.5) over  $100 \text{ deg}^2$  (north ecliptic pole)
- PanSTARRS will survey  $30,000 \text{ deg}^2$  (g, r, i, z, Y) to  $z \sim 1.5$ , the DES will survey  $5000 \text{ deg}^2$  in the South (g, r, i, z) to  $z \geq 1.3$ .
- The Large Synoptic Survey Telescope (LSST) will provide five band data for a solid angle  $\sim 20,000 \text{ deg}^2$ .
- The South Pole Telescope (SPT) will deliver a sample of more than  $20,000$  SZ clusters over  $4000 \text{ deg}^2$  extending to  $z > 1.5$ .
- The CMB mapping experiment Planck will deliver SZ observations of many massive and nearby galaxy clusters.
- Subaru Suprime-Cam
- LAMOST

# *Elektro-L*



First Elektro-L image, Feb 26  
Credit: NPO Lavochkin



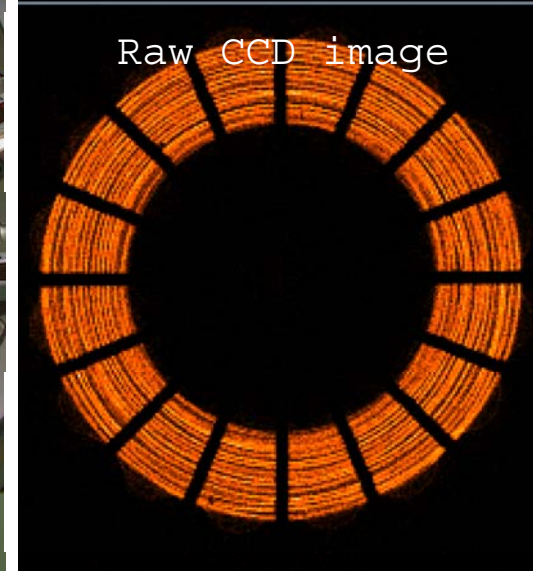
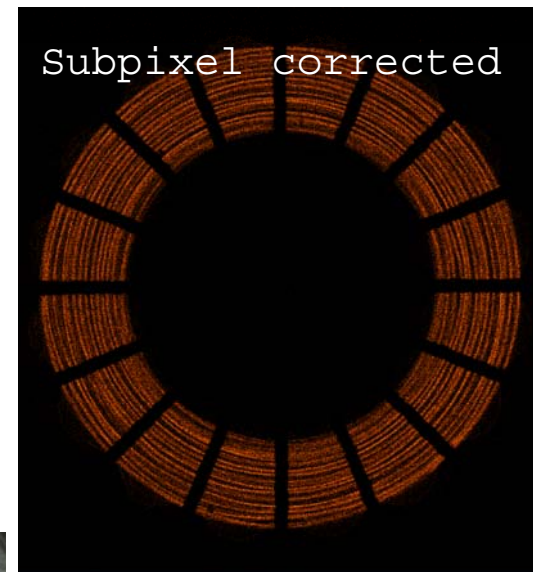
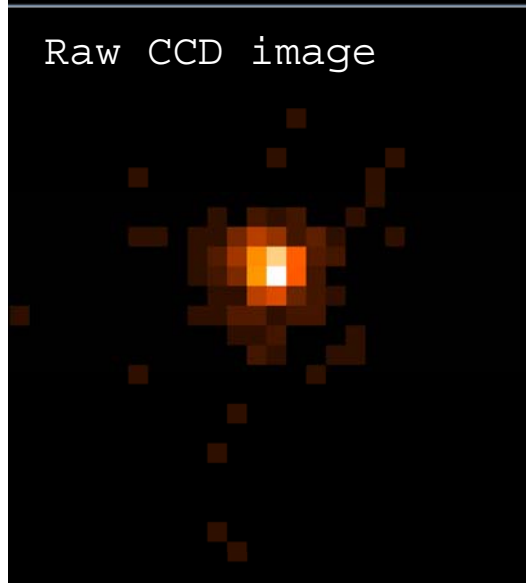
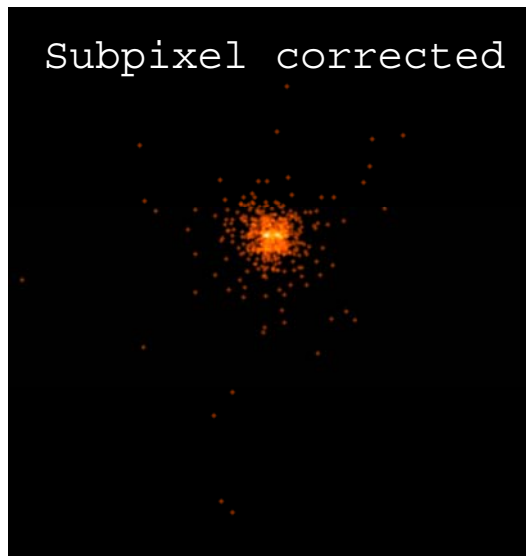
**January 20, 2011:** Zenit-Fregat successfully launches Elektro-L, Russian meteorological satellite on a Navigator platform

# Flight Mirror Module test

March, 2011, PANTER:

First Flight Mirror Module (FM1a)  
test (15 shells)

Mirror shells produced via Ni-  
electroforming and integrated  
by Media Lario Technologies/I

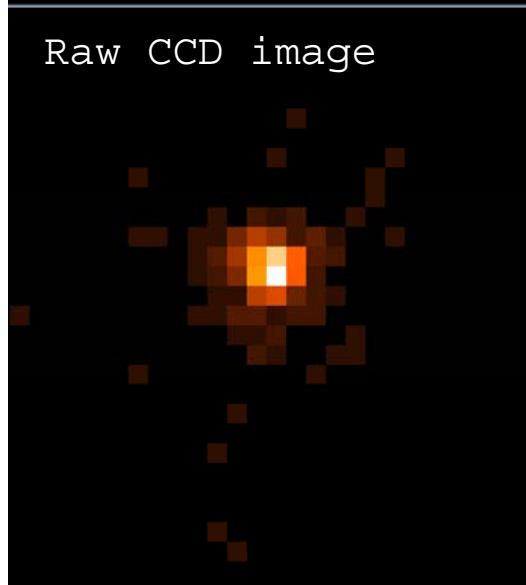
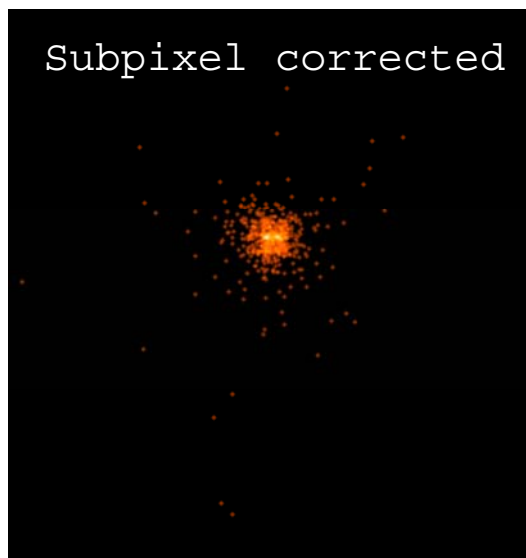


In focus image 1.49 keV

Intrafocal image 1.49 keV



# Flight Mirror Module test

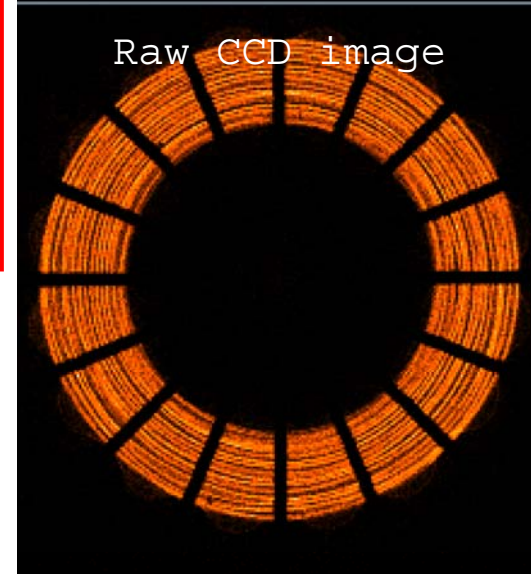


In focus image 1.49 keV

March, 2011, PANTER:  
First Flight Mirror Module (FM1a)  
test (15 shells)

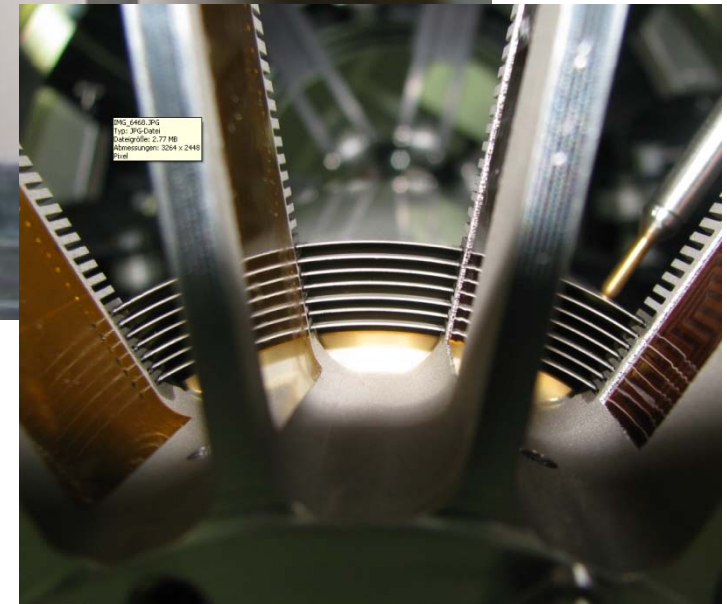
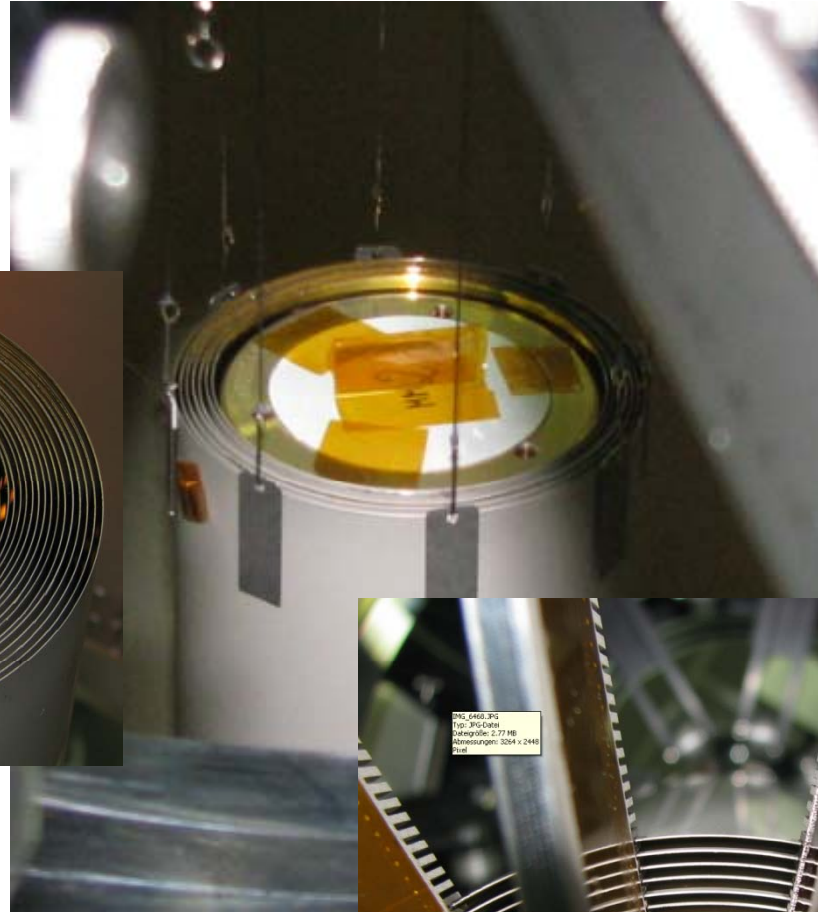
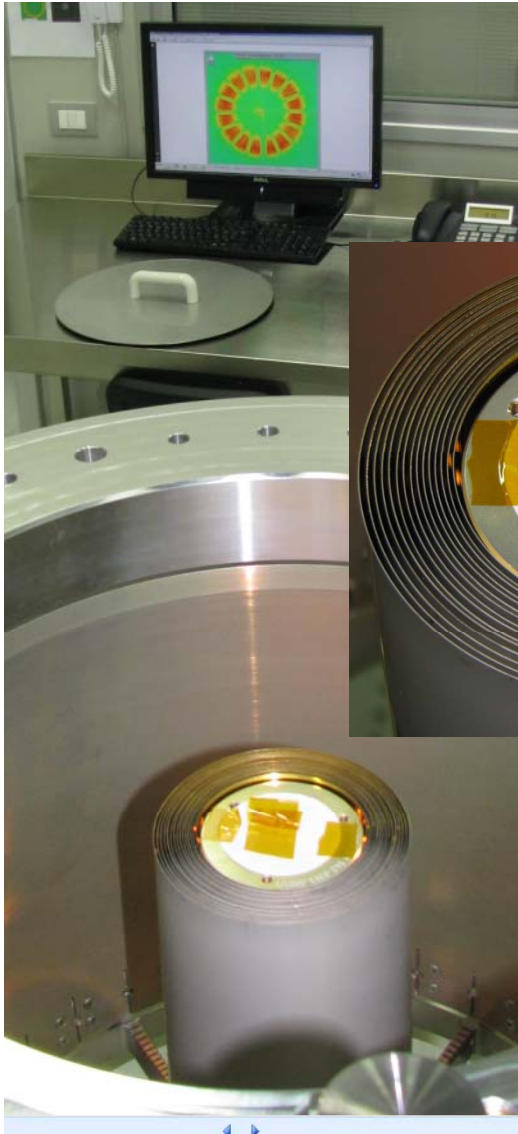
**HEW 13.1" Al-K (1.49keV)**  
[spec ( < 15" )]

**HEW 15.2" Cu-K (8.0 keV)**  
[spec ( < 20" )]



Intrafocal image 1.49 keV

# *Flight Mirror Modules 1a , 2a*



# Programmatic Status

- June 2006 Proposal to DLR
  - Nov. 2006 Mission Definition Review
  - Mar. 2007 MoU between Roskosmos & DLR
  - April 2007 eROSITA approved and funded by DLR
  - September 2008 Roskosmos decision on payload, orbit & launch
  - July 2009 Additional funding by MPG and DLR
  - August 2009 Detailed Agreement between Roskosmos and DLR
  - October 2009 Preliminary Design Review
  - December 2009 15 arcsec on-axis resolution goal reached.
- 
- since fall 2009 eROSITA in phase C/D
  - eROSITA completely funded by DLR, MPG, and MPE (~75M€)
  - all major contracts placed since 2009
- 
- no major problems, "normal work"
  - slight, accumulated delays -> Launch likely in 2013 Q2

2012 in Байконур

Thank you!

