The Platinum Age

eROSITA - A new X-ray All-sky Survey

eXTENDED **RO**ENTGEN **S**URVEY WITH AN **I**MAGING **T**ELESCOPE **A**RRAY

Peter Predehl for the eROSITA Team:

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Cooling, Thermal Engineering: M. Fürmetz + students
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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:

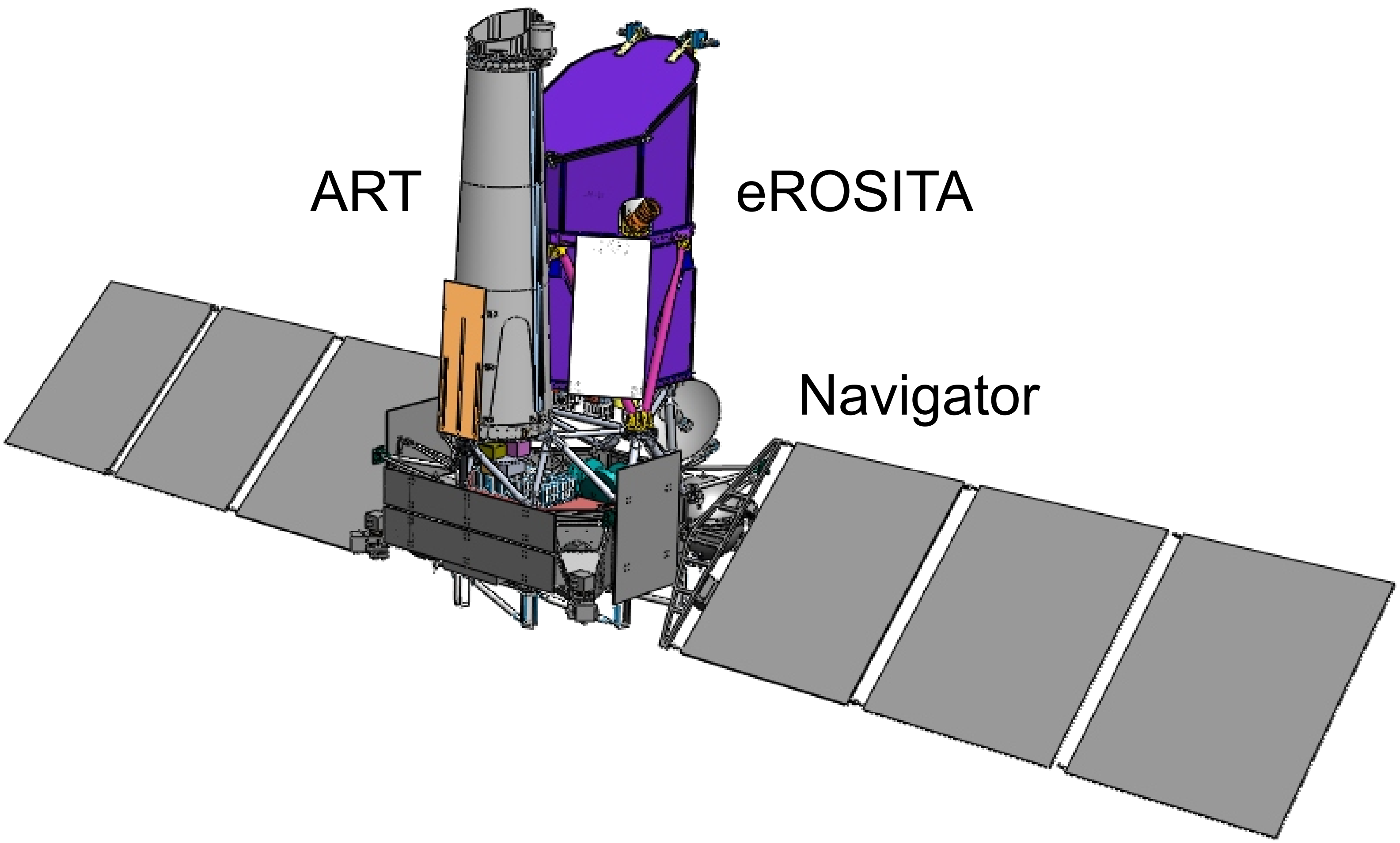
Max-Planck-Institut für extraterrestrische Physik, Garching/D
Univ. Erlangen-Nürnberg/D
Univ. Tübingen/D
Univ. Hamburg/D
Astrophysikalisches Institut Potsdam/D
Max-Planck-Institut für Astrophysik/D
Space Research Institute IKI, Moscow/Ru
Universität Bonn
Univ. München

Industry:

Media Lario/I	Mirrors, Mandrels
Kayser-Threde/D	Mirror Mechanics
Carl Zeiss/D	Mirror Mandrels
Invent/D	Telescope Structure
pnSensor/D	CCDs
EHP/B	Cooling
RUAG/A	Mechanisms
HPS/D,P	MLI

+ many small companies

Spektrum-Roentgen-Gamma



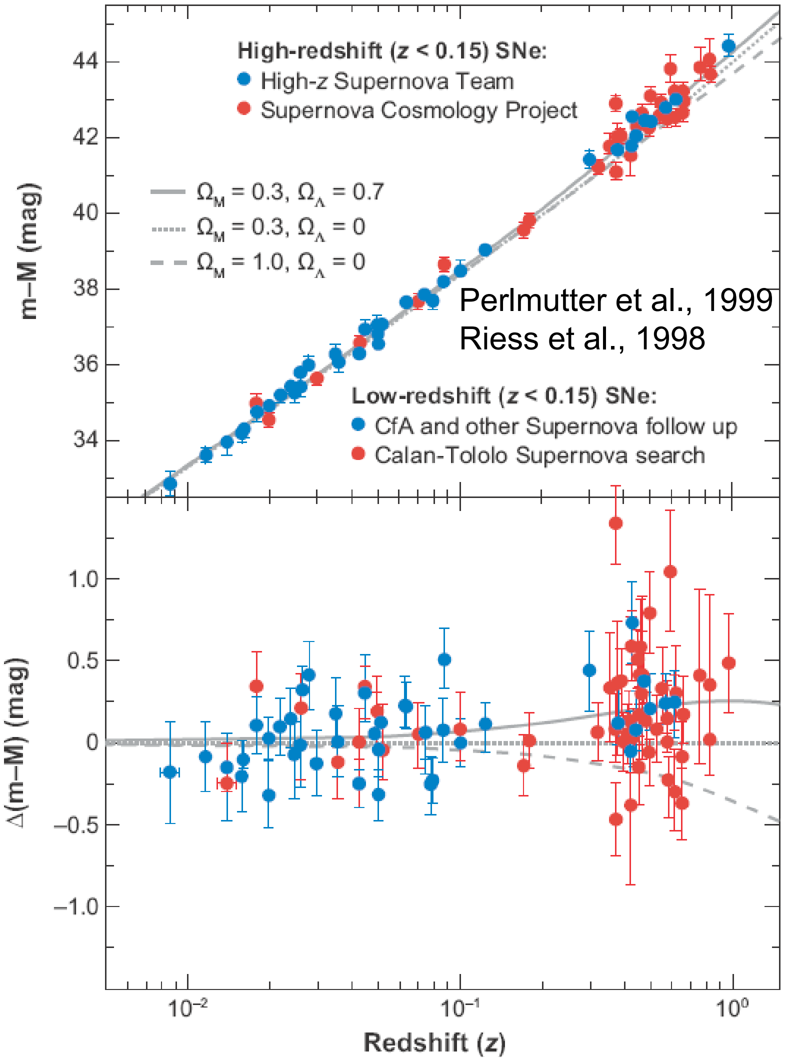
Design Driving Science

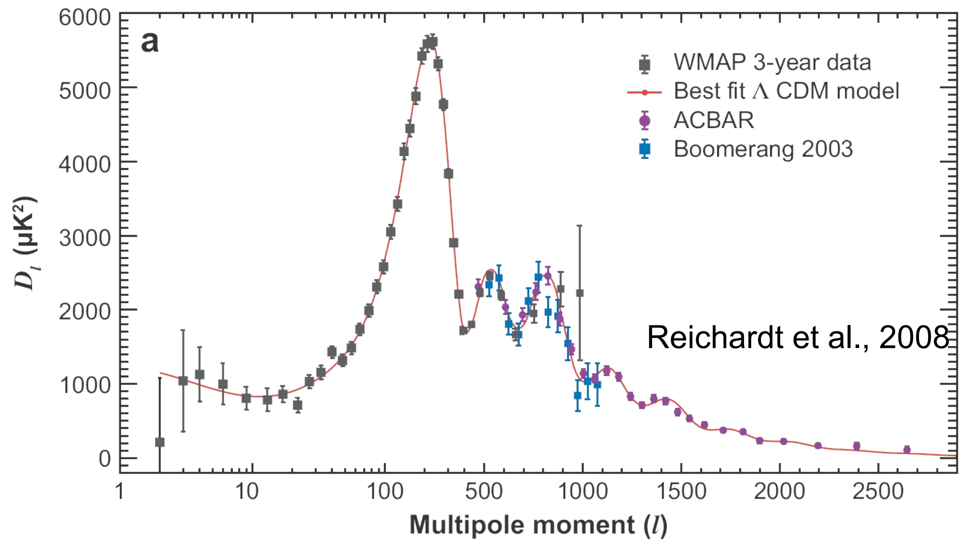
- Constrain parameters of Dark Energy

- Detectability of 100.000 Clusters of Galaxies, $z < 1.5$
  - All-sky survey with sensitivity 6×10^{-14} erg cm^{-2} s^{-1}
  - Deep survey field(s) (~100 sqdeg) with 5×10^{-15} erg cm^{-2} s^{-1}
  - Individual pointed observations

- Instrument:
  - Moderate angular resolution (< 30 arcsec, aver. over FoV)
  - Large collecting area (> 2000 cm^2 @ 1keV)
  - Large FoV (1° Ø)
  - Long duration (survey 4 years ← → 1/2 year (ROSAT)

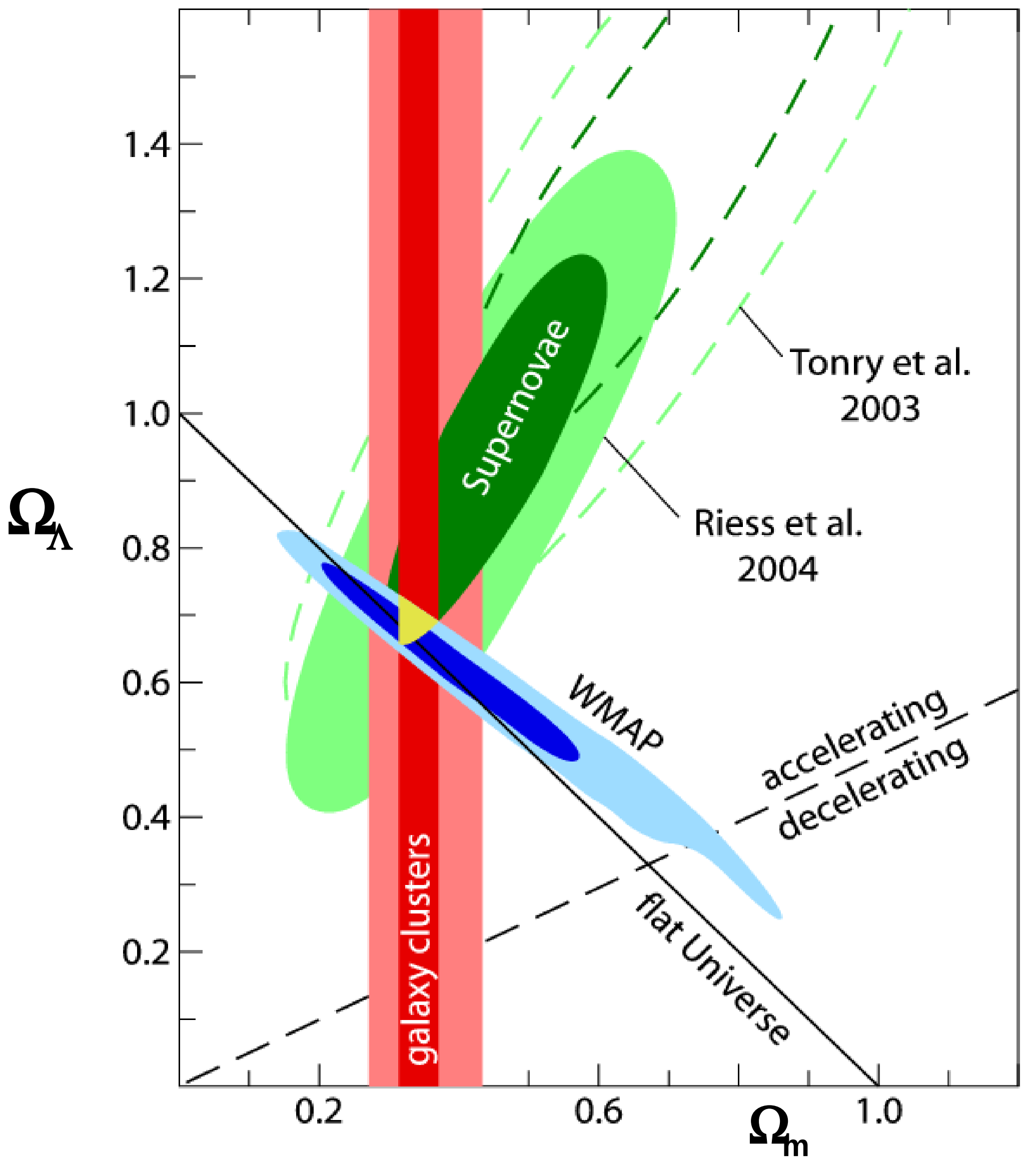
Observational constraints





- Universe is flat
- Expansion is accelerating

Concordance Model



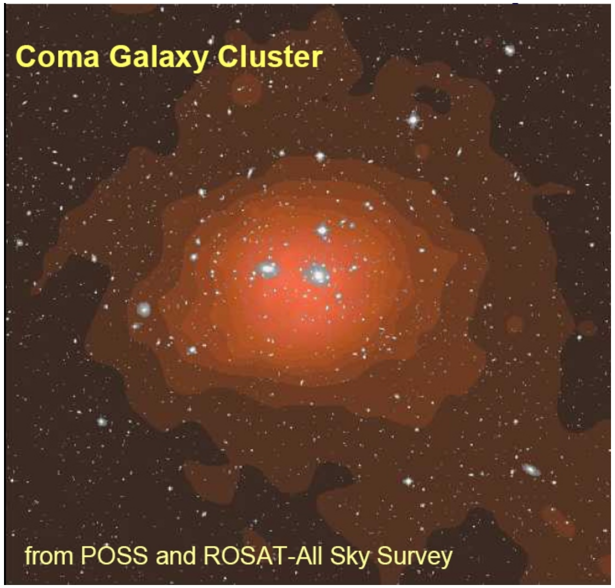
WMAP → Flat Universe
SN Ia → Accelerated Expansion
Clusters → Matter density

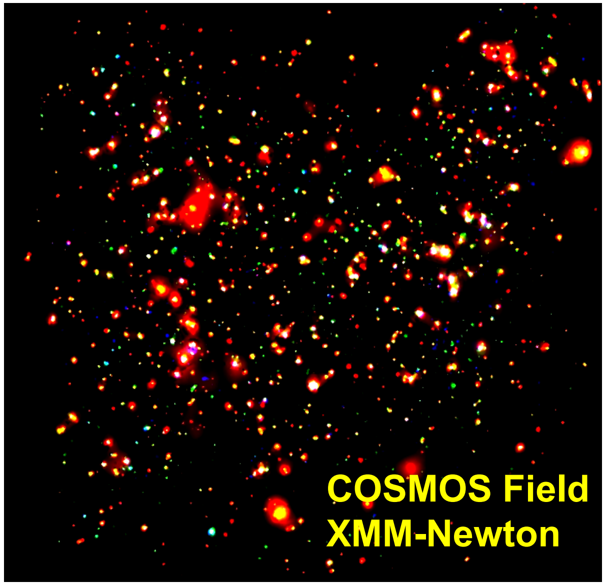
WMAP results from Spergel et al. 2003

REFLEX results from Schuecker et al. 2003 (three weeks before WMAP publication)

Equation of state:
$p(z) = w_x(z) * \rho\ (\quad z)$

Why are we doing this in X-rays?





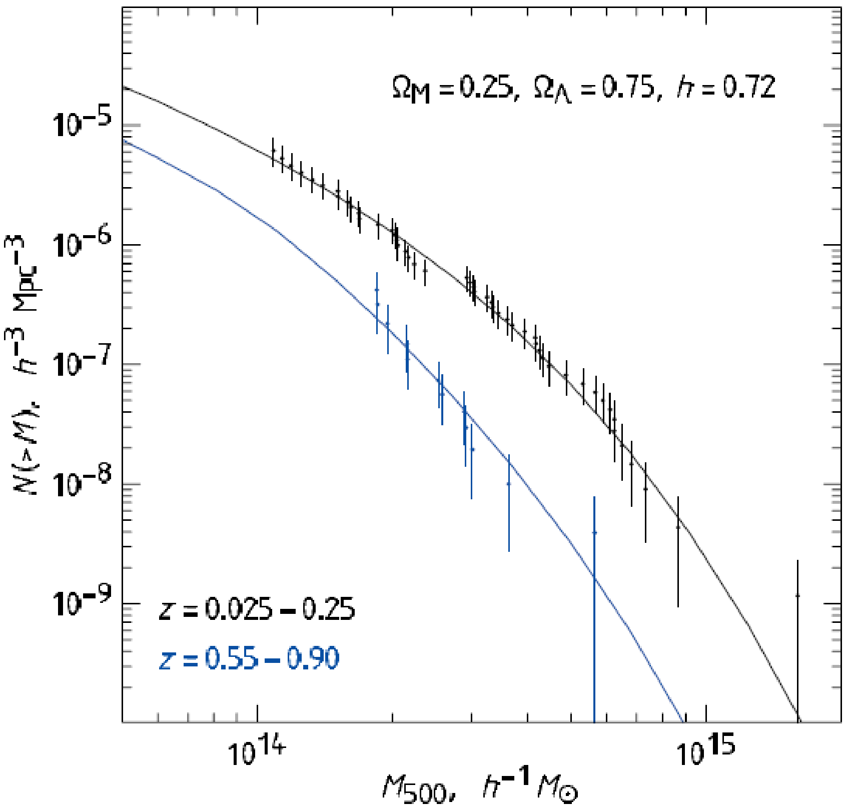
In X-rays we see clusters as one continuous entity

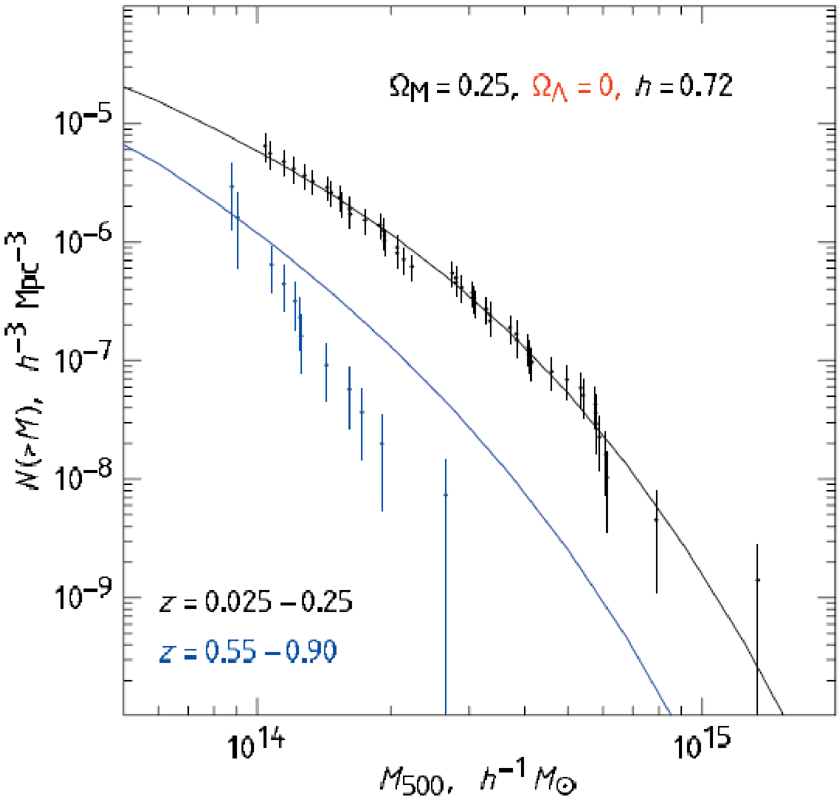
Clusters of galaxies are the largest gravitationally bound entities in the universe

Most cosmological studies involving galaxy clusters are based on X-ray surveys

- Gravitational DM collapse from initial density fluctuations
- Gas heated to X-ray temperatures by shocks, compression
- Evolution of population governed by underlying cosmology (**DM** & DE)

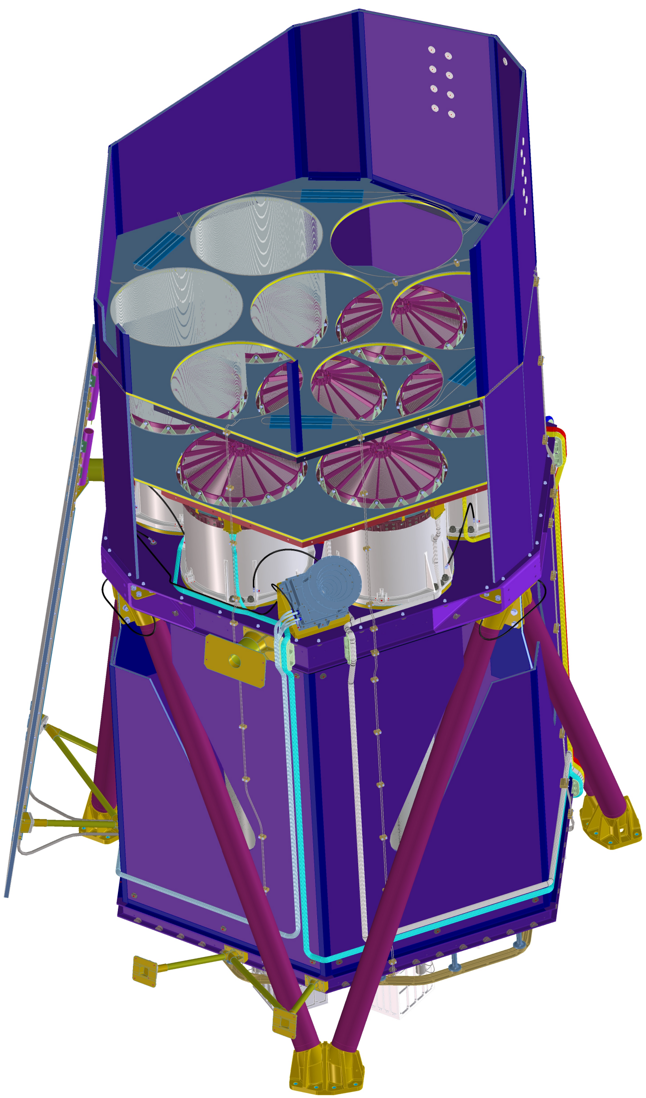
Cluster mass function vs. cosmological model

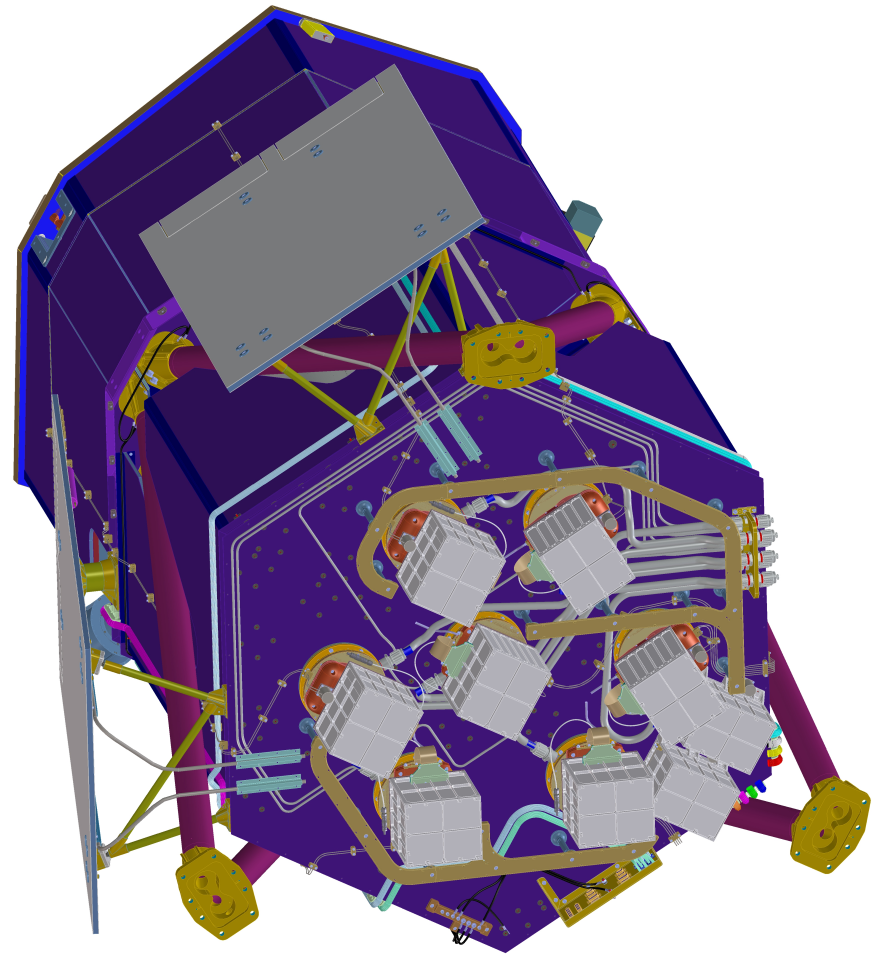




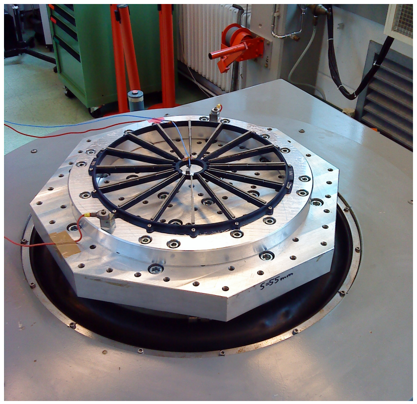
Vikhlinin et al., 2009

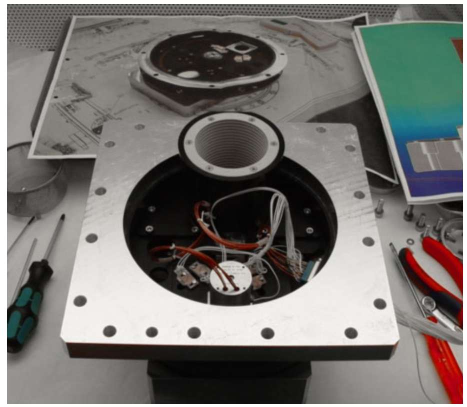
eROSITA Telescope

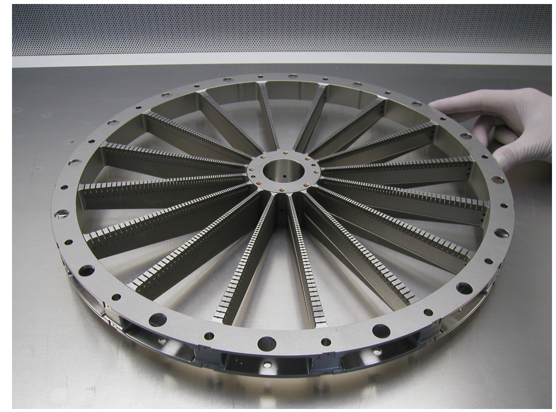


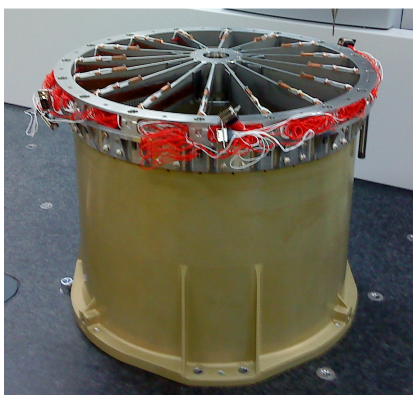


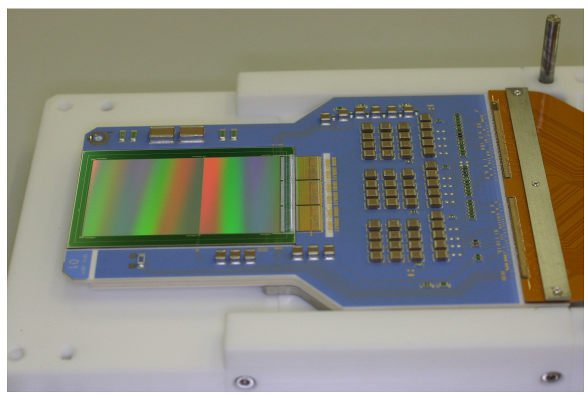
Hardware Development

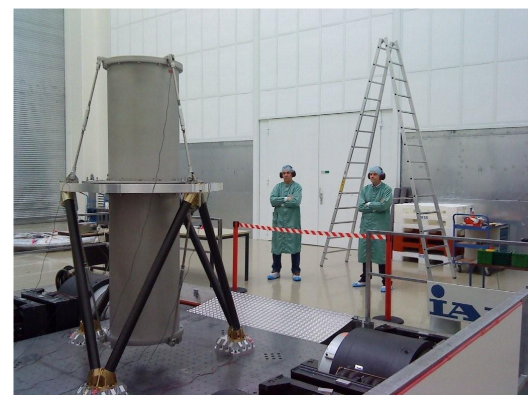












Everything has to be fabricated eight times!

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

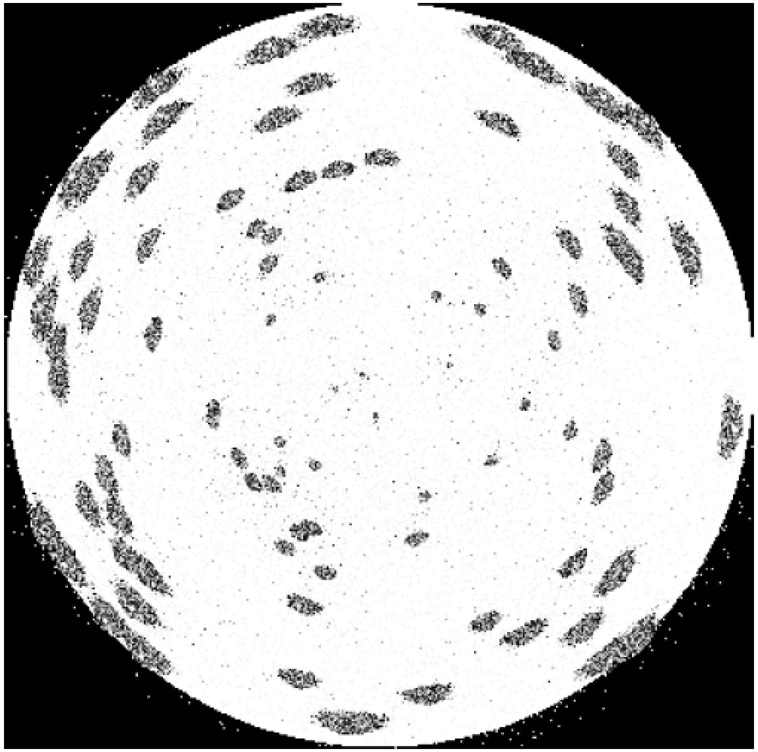
Size	28mm x 28mm
FoV	61 arcmin Ø
Pixelsize	75 µm
integ. time	50 msec
energy resol.	140 eV @ 6 keV

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

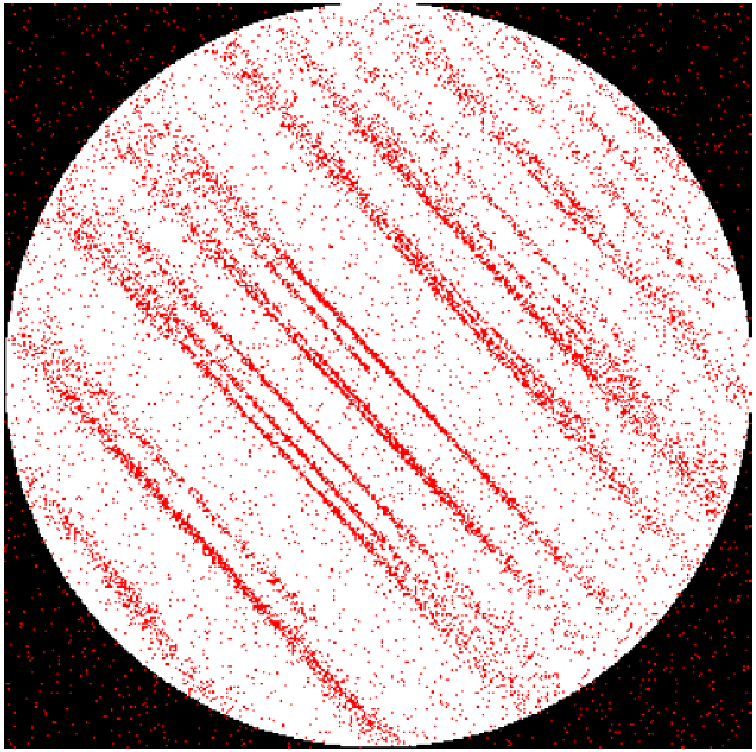
eff. area	2300 cm^2 (1keV)
	500 cm^2 (5 keV)
Grasp	700 cm^2 deg^2 (1keV)
Sensitiv.	6×10^{-14} cluster, all-sky
	1×10^{-14} cluster, deep
	1×10^{-15} point-s, all-sky
	3×10^{-15} point-s, deep

eROSITA Simulations

by Chr. Schmid



Pointing

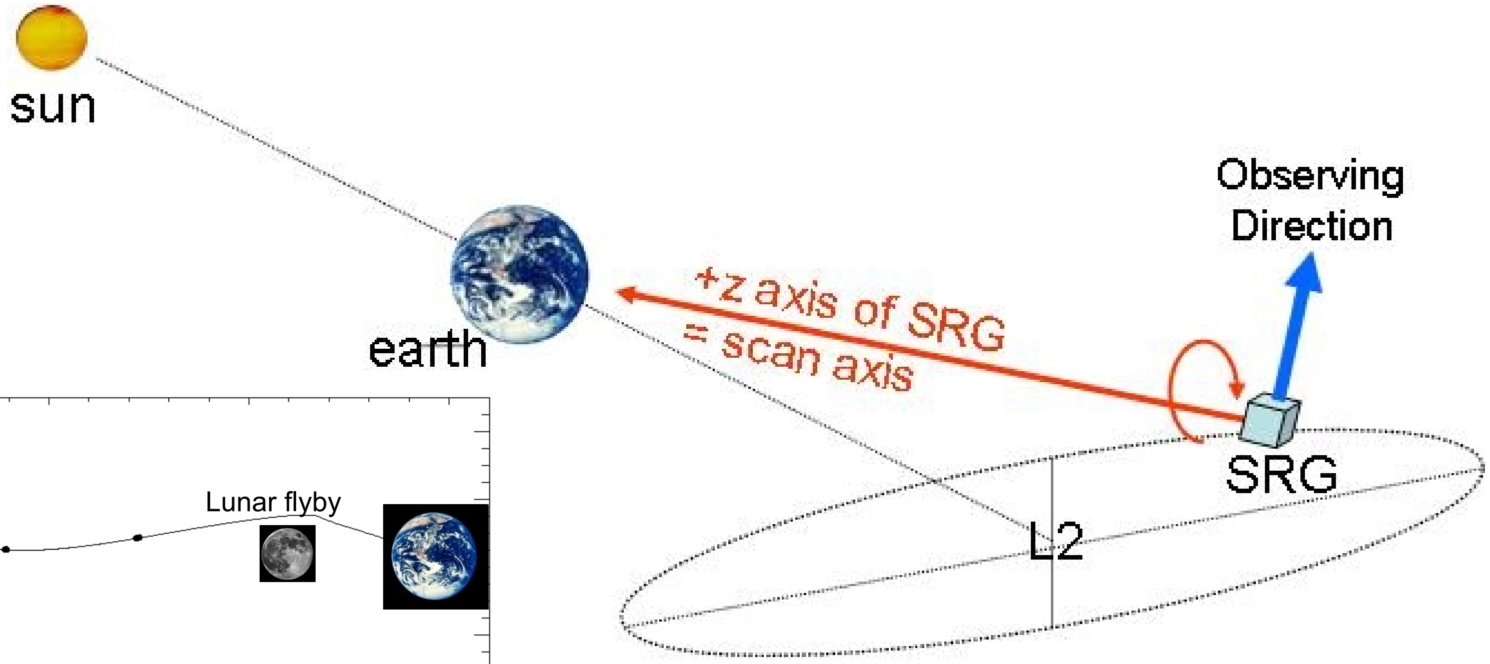


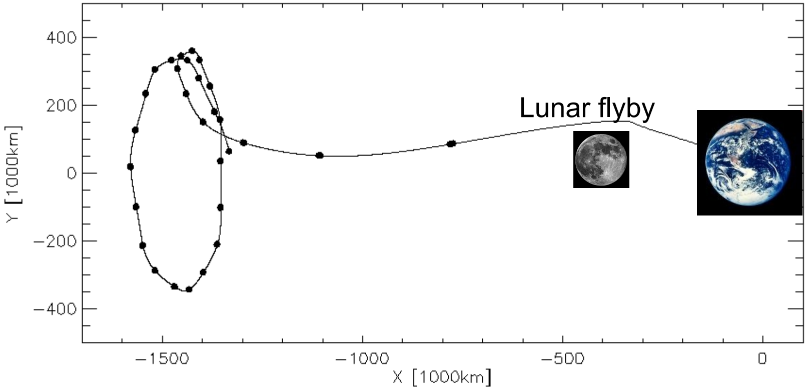
Survey

Off-axis blurring of a Wolter-I telescope →
PSF has to be averaged over the FoV

Mission Scenario

M. Fürmetz, 2010

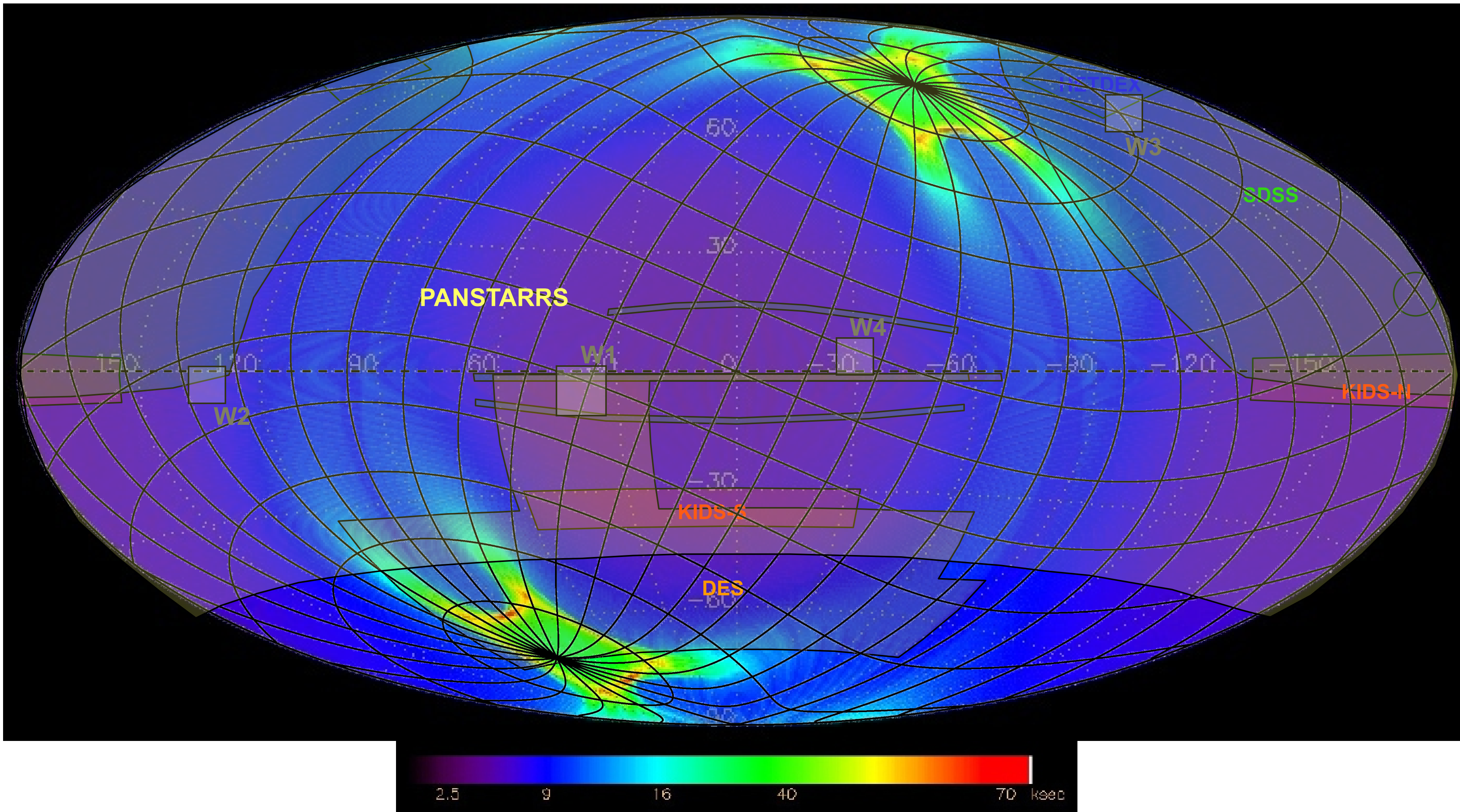




Angle between sun and Earth max. 13°
Scan-Axis always pointing towards Earth (antenna!)
Scanspeed less than in LEO, ~ 4h/revolution

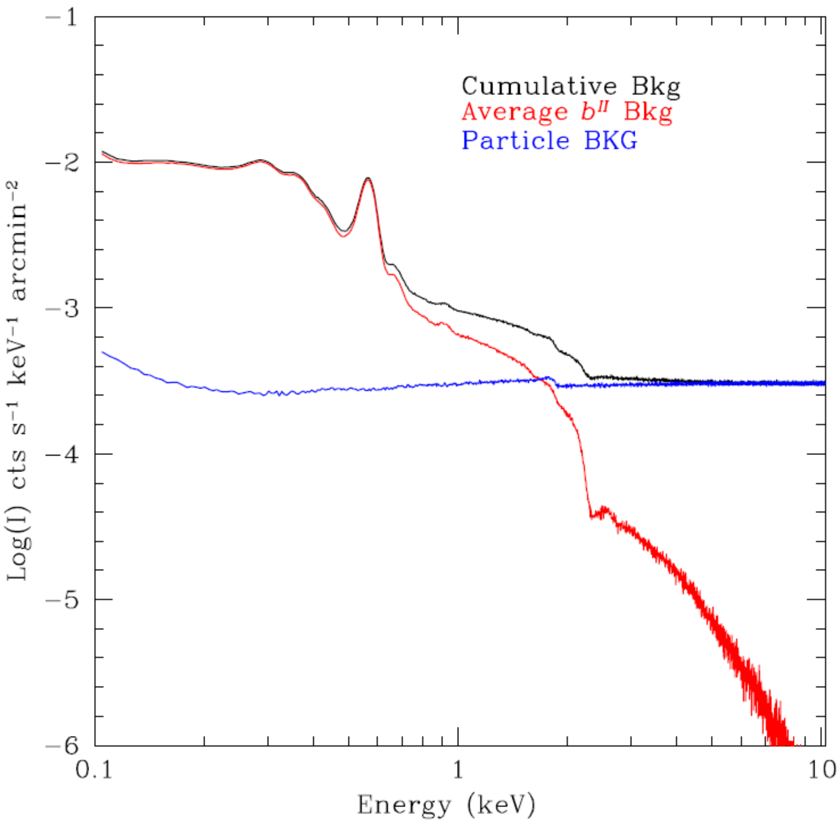
eROSITA Exposure

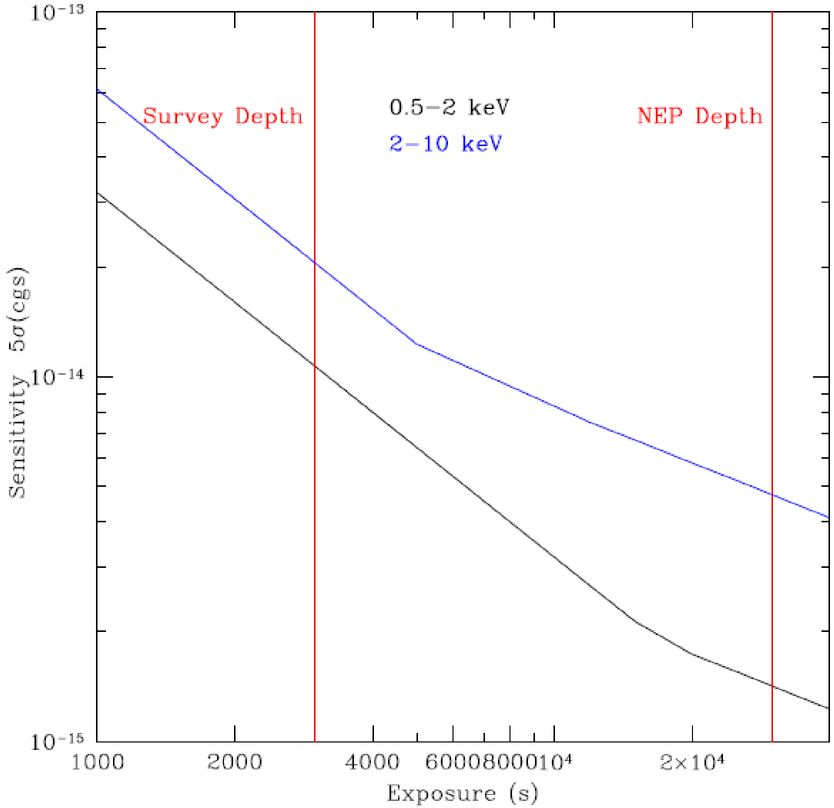
M. Fürmetz, P. Friedrich, 2010



Background and Sensitivity

N. Cappelluti, 2010





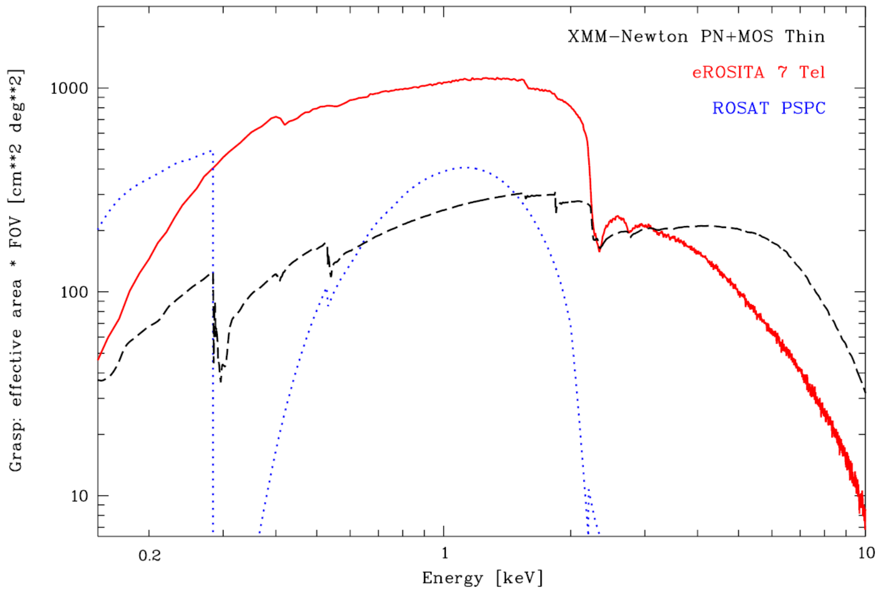
Soft background dominated by galactic/cosmic component.

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

eROSITA Sensitivity

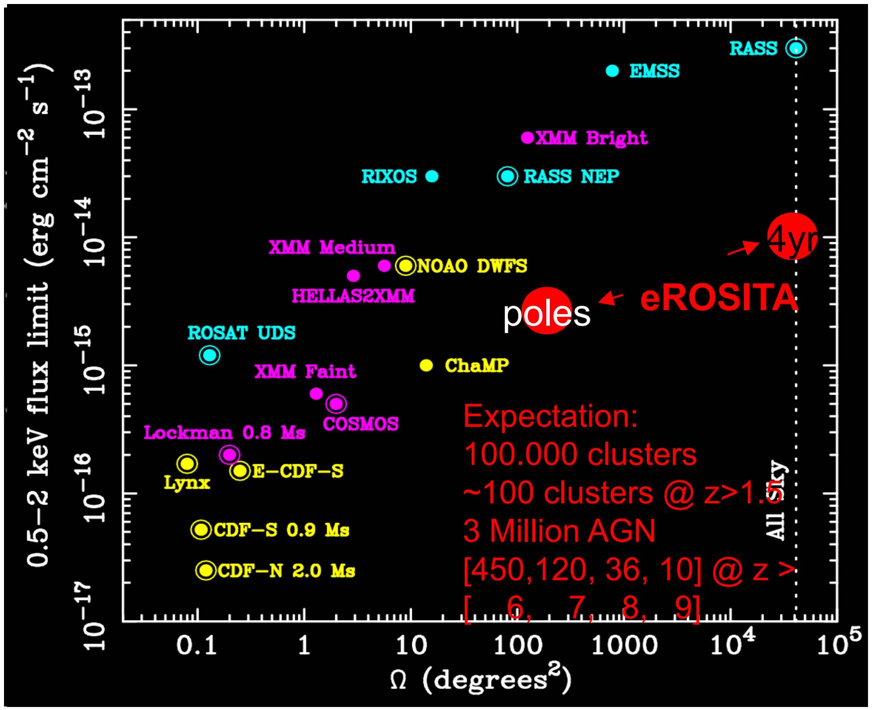
Grasp



7 telescopes, 350 cm² each
large field of view (61 arcmin Ø)

~ 2 × XMM-Newton (MOS+PN)

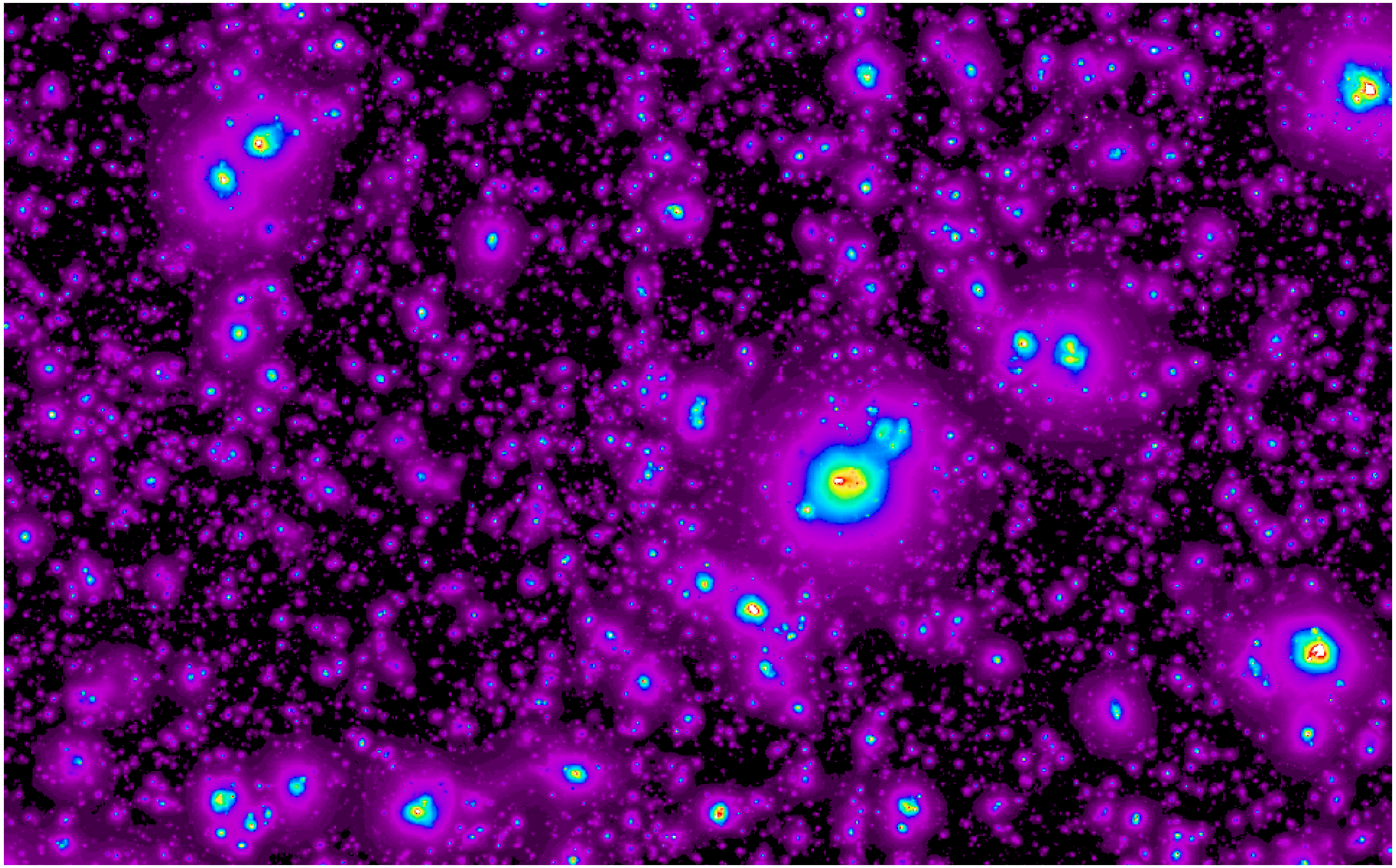
F-Ω



for clusters
for point sources

eROSITA Simulations

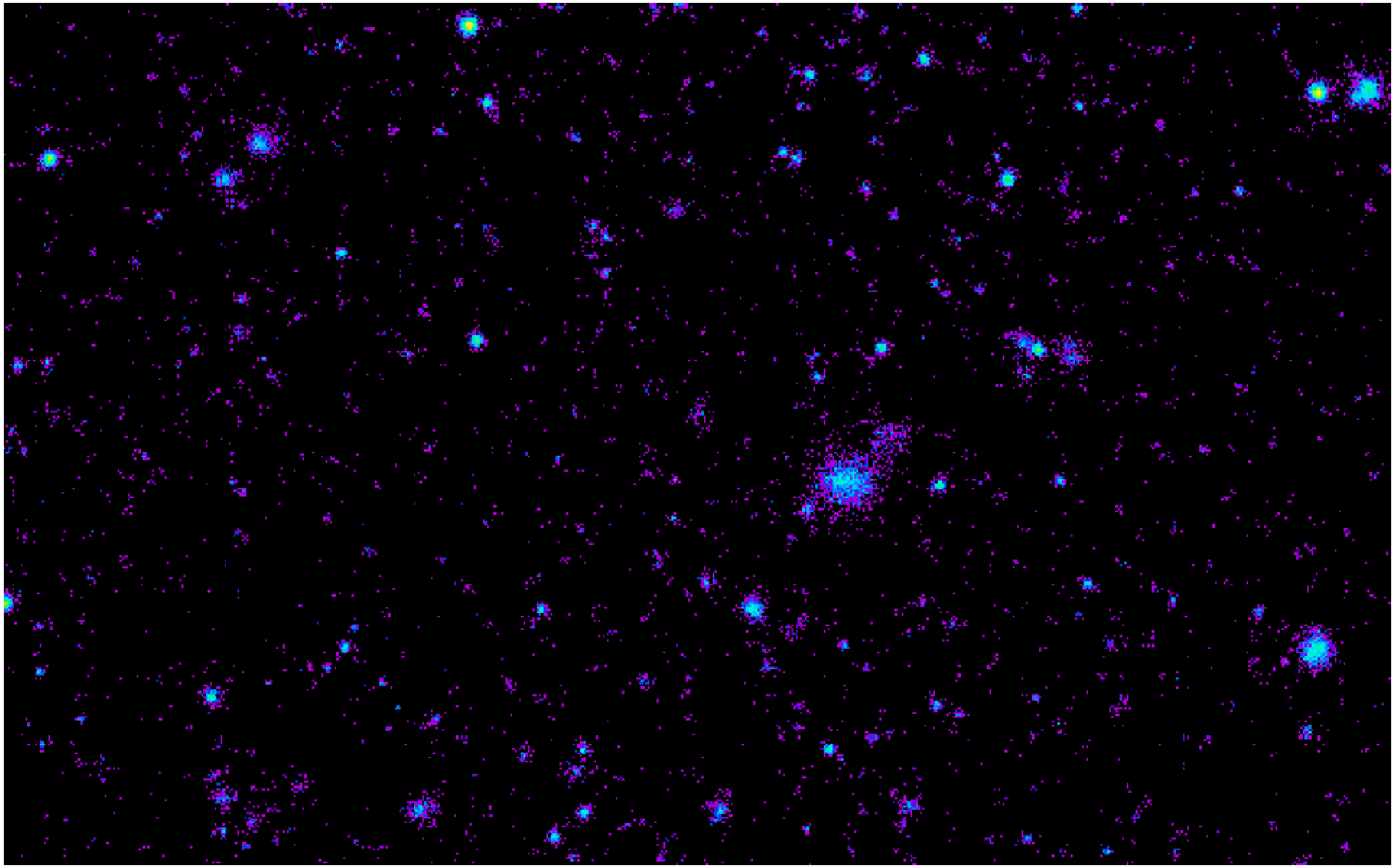
M. Mühlegger, 2010



Surface brightness map (1° × 1,6°) from HD simulation

eROSITA Simulations

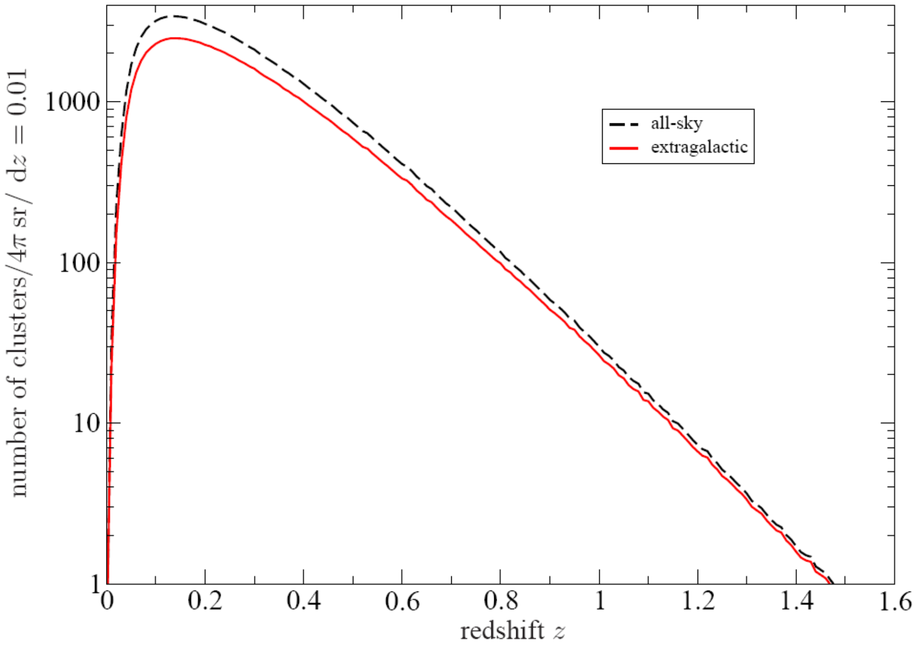
M. Mühlegger, 2010

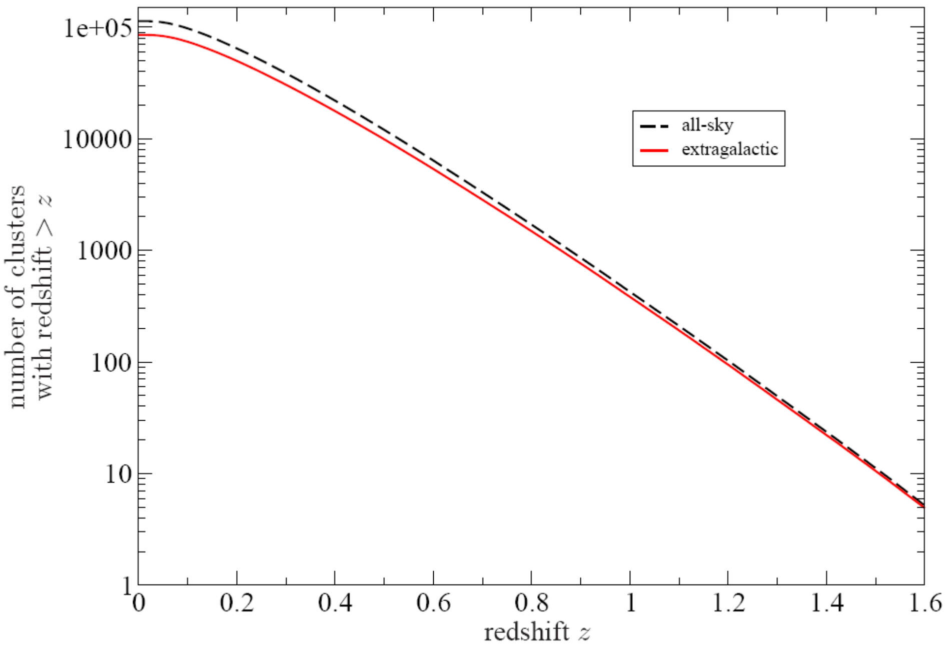


Same region, AGN+BKGR+CLusters, 3ks, PSF convolved

Expected number of clusters

M. Mühlegger, 2010

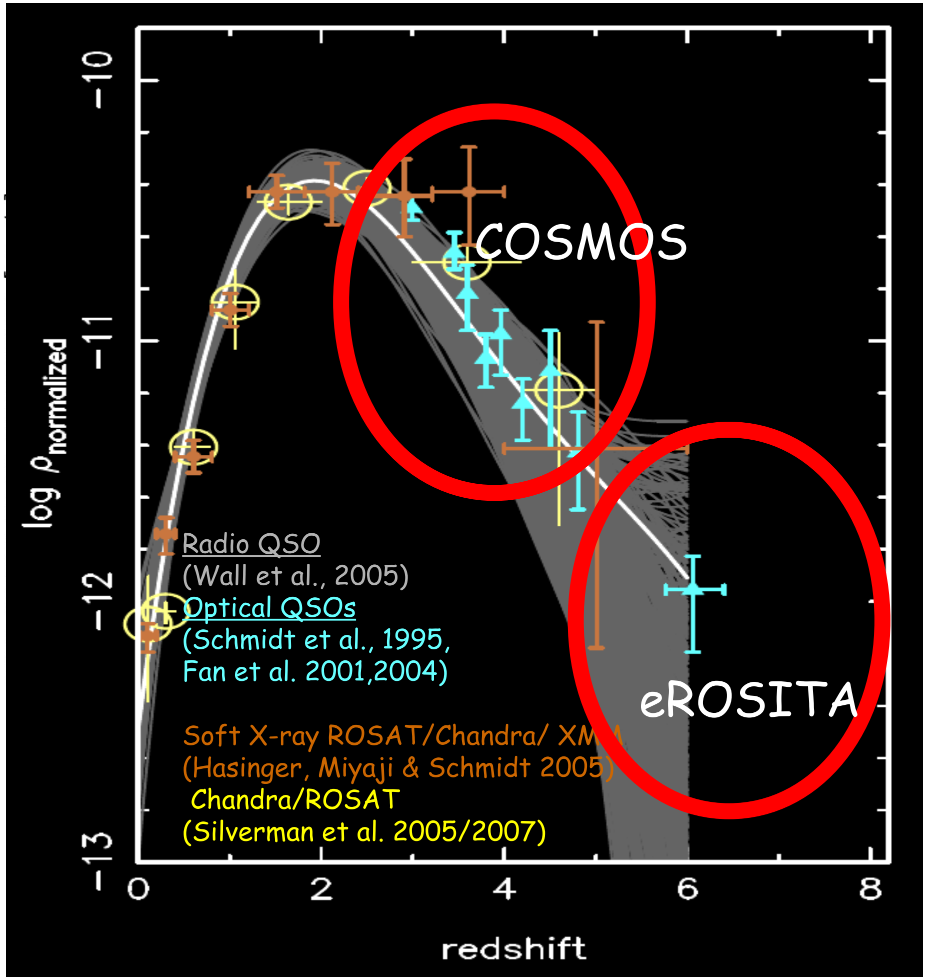




100 cts for detection

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 (~3-10% at most?)
- Substantial optical/near-IR follow-up (or companion surveys) required
- Accurate redshifts (dz ~ 0.02) to z < 1.5 for > 100,000 clusters from multi-band photometry, covering wavelength of <1m for clusters at z=1.5, deep enough to obtain ~10 cluster members.

- The Sloan Digital Sky Survey (SDSS) provides spectroscopic redshifts of cluster galaxies to z~ 0.6 over ~7000 deg2.
- PanSTARRS will survey 30,000 deg2 (g, r, i, z, Y) to z~1.5, the DES will survey 5000 deg2 in the South (g, r, i, z) to z≥1.3.
- The Large Synoptic Survey Telescope (LSST) will provide five band data for a solid angle ~20,000 deg2.
- The South Pole Telescope (SPT) will deliver a sample of more than 20,000 SZ clusters over 4000 deg2 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

Programmatic Status

- June 2006 — Proposal to DLR
- Mar. 2007 — MoU between Roskosmos & DLR
- April 2007 — eROSITA approved and funded by DLR

- **Summer 2008: — Nothing but problems...**
  Mirrors, Payload, Costs

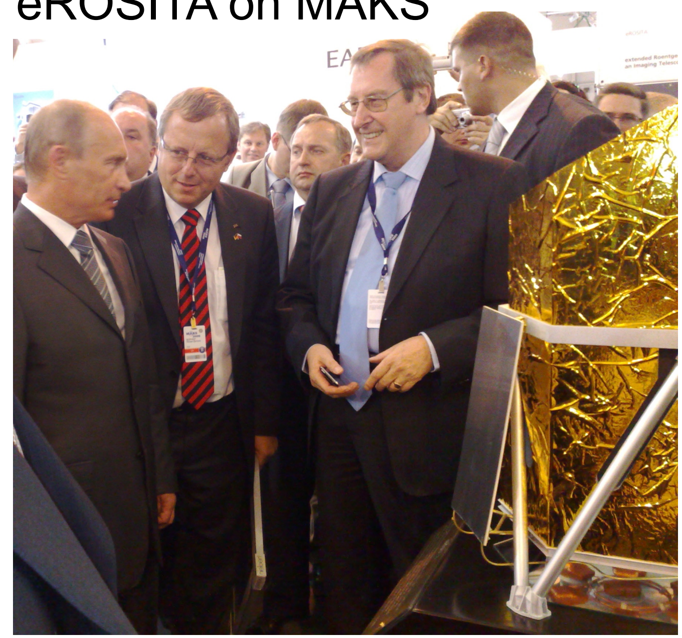
- September 2008 — Roskosmos decision on payload, orbit & launch
  ART-XC, L2-orbit, 2012 with Soyuz-Fregat from Baikonur
- May 2009 — Mirror-FM contract
  Media Lario Technologies, (Kayser-Threde, Zeiss)
- June 2009 — Additional Funding by MPG
- July 2009 — Additional Funding by DLR
- August 2009 — 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**

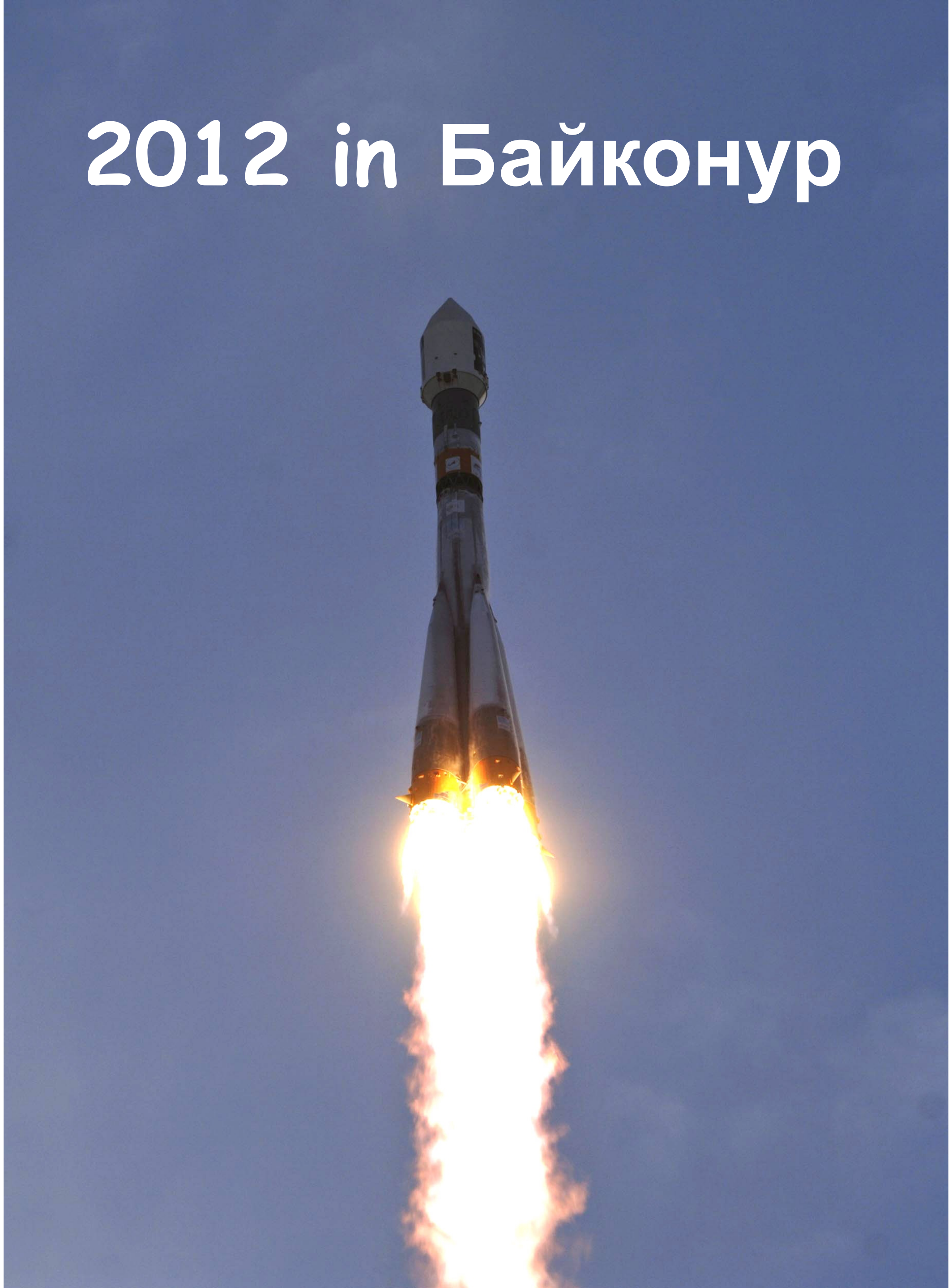
Programmatic Status

Signature of the "Detailed Agreement"
(Reichle, Wörner, Perminov)

eROSITA on MAKS



Mr. Putin gets informed about Dark Energy...


2012 in Байконур