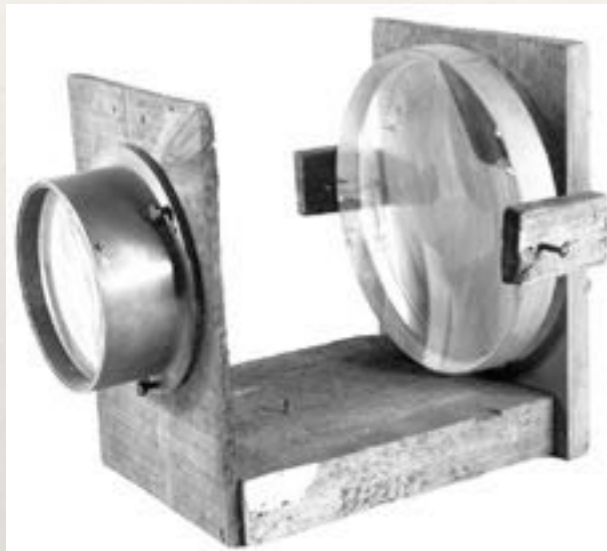

SURVEYING THE SKY FROM RADIO TO X-RAYS

Marcus Brüggen
University of Hamburg

WIDE-FIELD IMAGING: SCHMIDT PLATE



Mitteilungen der Hamburger Sternwarte in Bergedorf.

Band 7. Nr. 36.

Ein lichtstarkes komafreies Spiegelsystem*).

(Mit Tafel I und II)

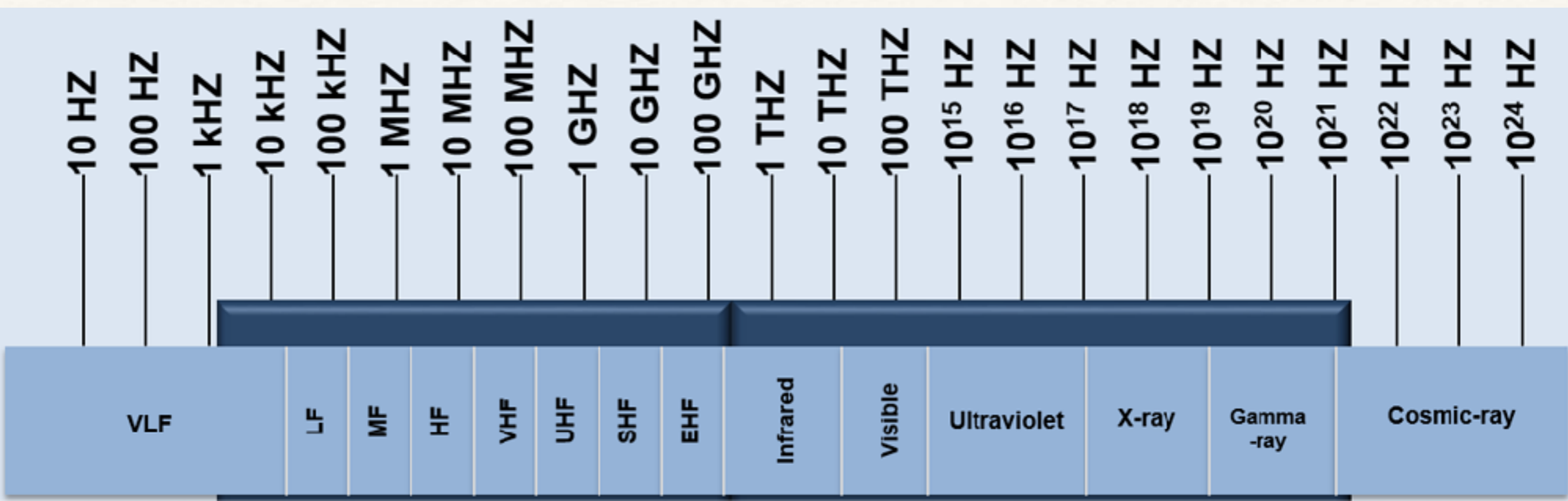
Wenn man den Lichtverlust bei einem Spiegel und bei einem Linsensystem miteinander vergleicht, so ergibt sich, daß bei gleichem Öffnungsverhältnis der Spiegel einen geringeren Lichtverlust aufweist als das Linsensystem. Ein frisch verilberter Spiegel reflektiert mindestens 90% des auffallenden Lichtes, während ein Zweilinsensystem höchstens 80%, und ein Dreilinsensystem höchstens 70% des einfallenden Lichtes durchläßt. Bei größeren Linsen wird durch die stärkere Absorption kurzwelliger Strahlen durch das Glas die Sache noch ungünstiger.

Bei großen Fernrohren wäre daher der Parabolspiegel im allgemeinen vorteilhafter als ein Linsensystem, leider wird aber bei großen Öffnungsverhältnissen das brauchbare Gesichtsfeld durch die Koma sehr beengt. Bei einem Öffnungsverhältnis 1 : 3 beträgt die Streuung durch Koma bei einem Gesichtsfeld Durchmesser von nur 1 Grad bereits 37 Bogensekunden, außerdem kommt noch die Streuung durch Astigmatismus von 5 Bogensekunden hinzu. Die Koma wächst direkt proportional mit dem Gesichtsfeld Durchmesser, der Astigmatismus quadratisch. Infolgedessen wird der Astigmatismus in der Nähe der Achse verschwindend klein und die Komarscheinung tritt rein auf, während sie in größerem Abstand von der Achse durch den Astigmatismus modifiziert wird.

Insofern ist der Parabolspiegel bei Öffnungsverhältnissen von 1 : 8 bis 1 : 10 dem gewöhnlichen Zweilinsensystem in bezug auf Bildschärfe überlegen, hinzu kommt noch, daß eine Farbenabweichung beim Spiegel vollständig fehlt. Nachteilig ist, daß die Lichtverteilung in den Streuungsscheibchen der Spiegelbilder eine einseitige ist, was bei Ausmessungen derselben systematische radiale Verschiebungen hervorbringen kann.

Nun aber mag darauf hingewiesen werden, daß sogar der rein sphärische Spiegel mit den Öffnungsverhältnissen 1 : 8 bis 1 : 10 noch gut verwendbar ist. Würde man die Öffnungsblende direkt vor dem Spiegel anbringen, so würde gegenüber dem Parabolspiegel kein Vorteil entstehen, da ja der sphärische Spiegel genau dieselben Fehler hat; außerdem käme noch die sphärische Aberration hinzu, die über das ganze Gesichtsfeld die vorhandenen Streuungen vergrößert. Wird aber die Öffnungsblende im Krümmungsmittelpunkt angebracht, so hat der sphärische Spiegel, abgesehen von der Längsaberration, überhaupt keine Streuungen mehr, Koma und Astigmatismus sind null. Die Bildfläche liegt dabei auf einer Kugeloberfläche, die als

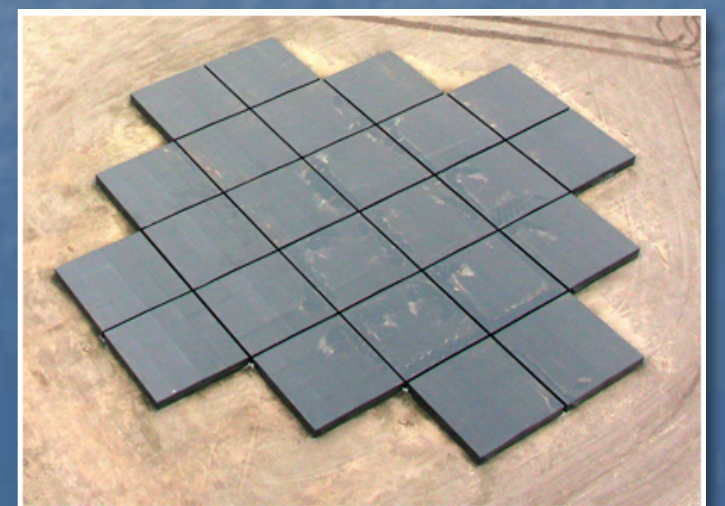
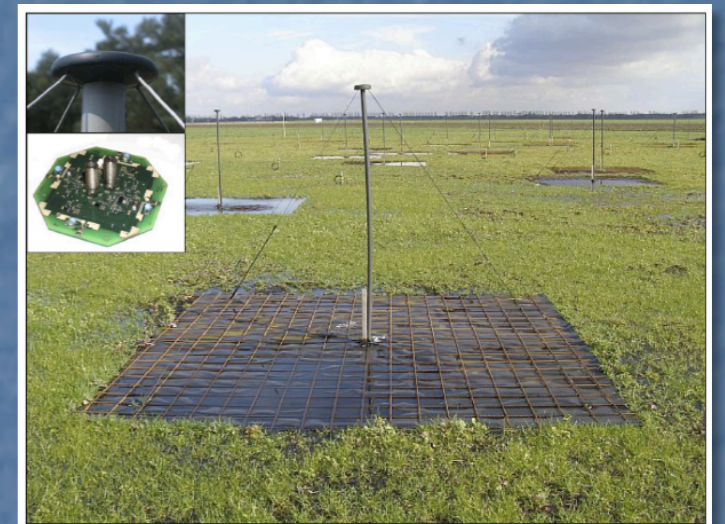
* Central-Zeitung für Optik und Mechanik, 57. Jahrgang Heft 1

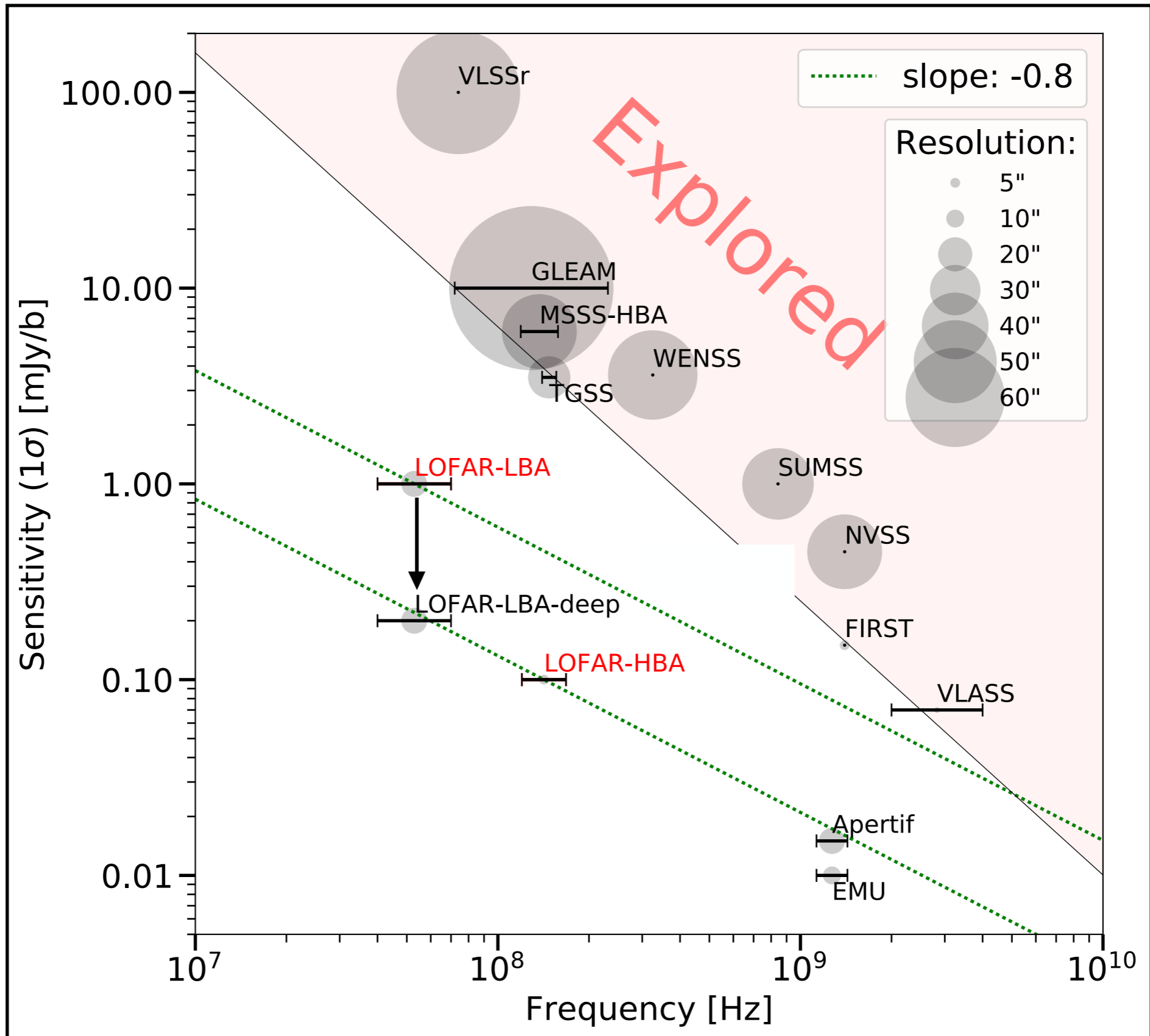


THE LOW FREQUENCY ARRAY – KEY FACTS

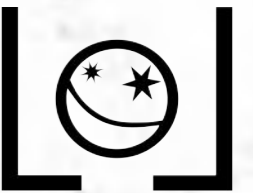


- The International LOFAR telescope (ILT) consists of an interferometric array of dipole antenna stations distributed throughout the Netherlands, Germany, France, UK, Sweden (+ Poland, ...)
- Operations started in December 2012
- Operating frequency is 10-250 MHz
- 1 beam with up to 96 MHz total bandwidth, split into 488 sub bands with 64 frequency channels (8-bit mode)
- < 488 beams on the sky with $\sim 0,2$ MHz bandwidth
- Low band antenna (LBA; Area ~ 75200 m²; 10-90 MHz)
- High Band Antenna (HBA; Area ~ 57000 m²; 110-240 MHz)





Frequency: 54 MHz
Pointings: 16
Coverage: 150 sqdeg
Resolution: ~45"
Rms noise: 3-6 mJy/b
Sources: ~5000



sky survey

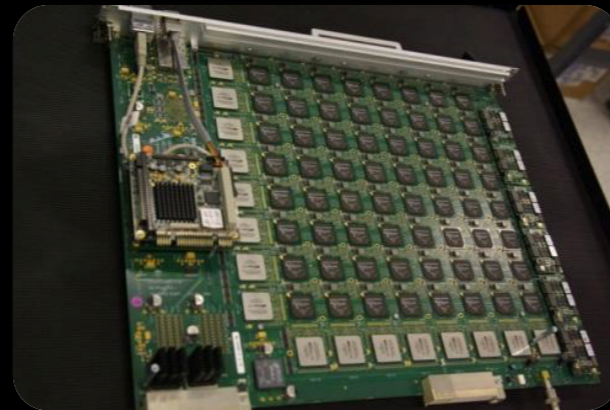
SKA: A LEADING BIG DATA CHALLENGE FOR 2020



Antennas



Digital Signal Processing (DSP)



To Process is HPC
2020: 100 PBytes/day
2028: 10,000 PBytes/day

Over 10's to 1000's kms

Transfer antennas to DSP
2020: 20,000 PBytes/day
2028: 200,000 PBytes/day

Over 10's to 1000's kms

HPC Processing
2020: 300 PFlop
2028: 30 EFlop



High Performance Computing Facility (HPC)

SKA: A LEADING BIG DATA CHALLENGE FOR 2020



Digital Signal Processing (DSP)

To Process is HPC
 2020: 100 PBytes/day
 2028: 10,000 PBytes/day

Antennas



1000's kms

	LOFAR	SKA
Raw Telescope	112 PB/yr	60 EB/yr
Archive Rate	6 PB/yr	100 PB/yr

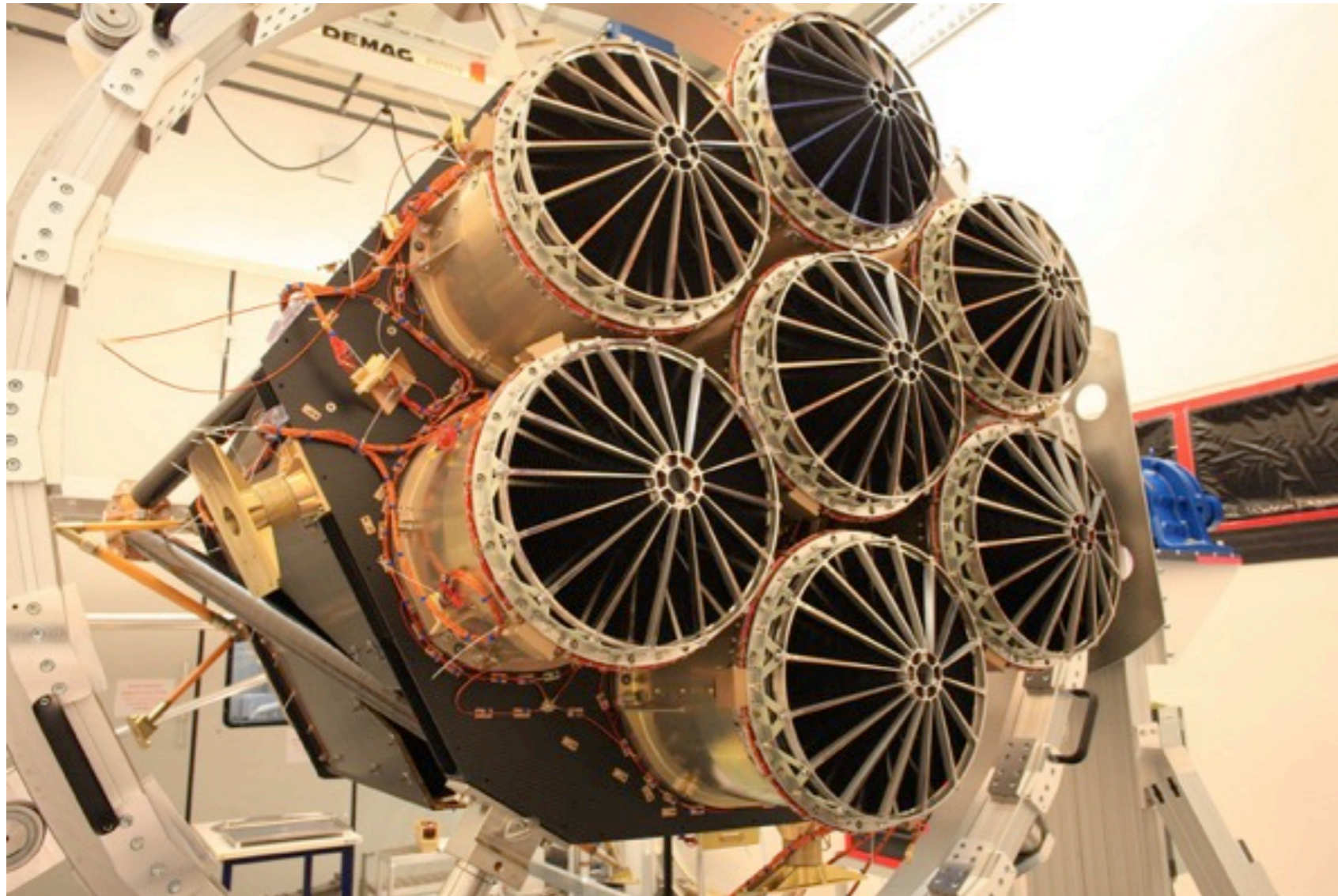


2020: 300 PFlop
 2028: 30 EFlop

High Performance
 Computing Facility (HPC)



7+1 Mirror assemblies



X-ray Baffle [MPE]

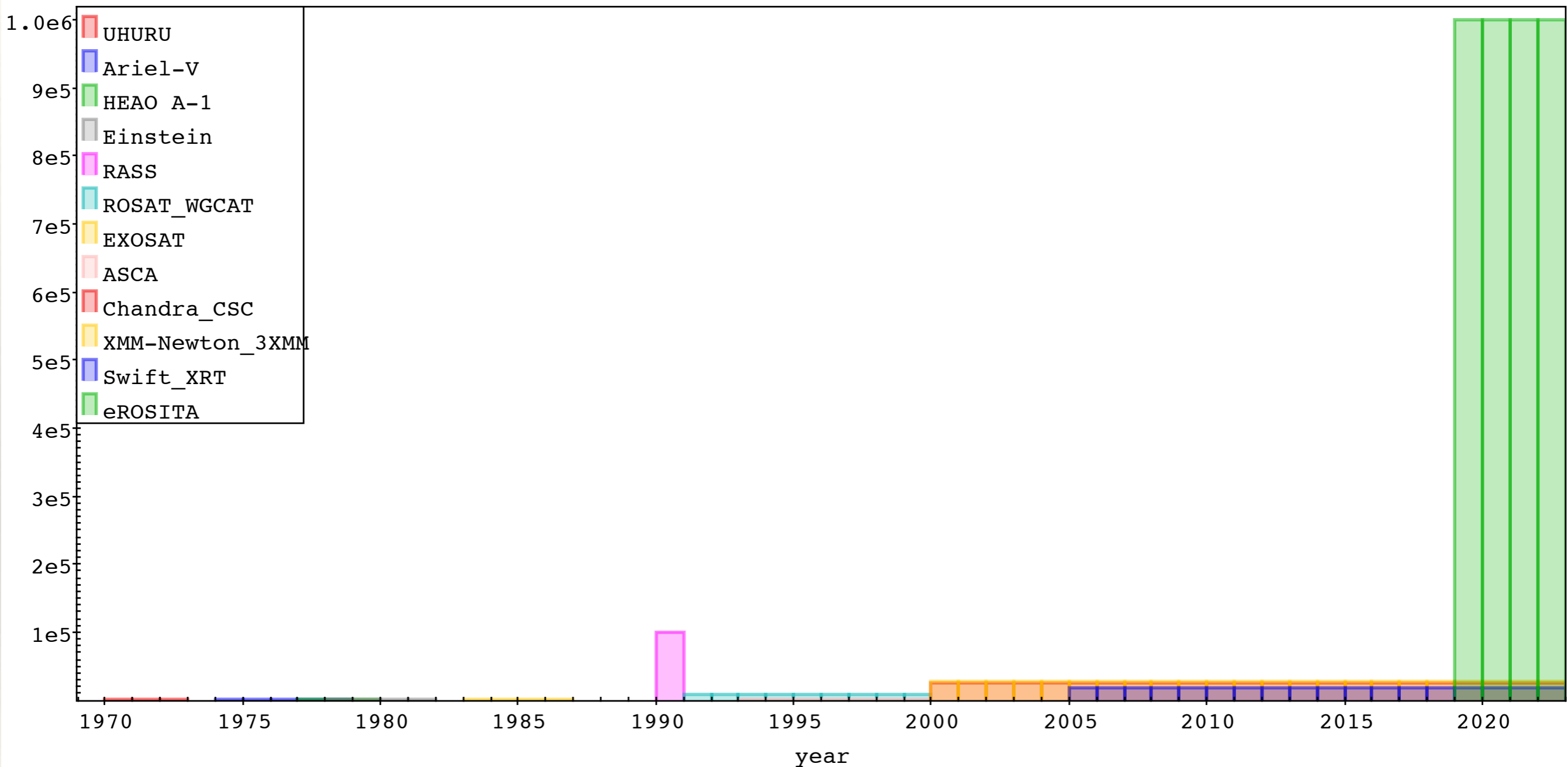
- 54 nested gold-coated nickel mirror shells
- Focal length: 1.6 m, Field of view: 1 degree (diameter)
- On-axis Half-Energy width (HEW) ~16.1" (nominal)
- X-ray baffle (10 μ m precision alignment): 92% stray light reduction
- Calibration of all 8 telescopes at PANTER completed in June 2016



eROSITA surveys in context



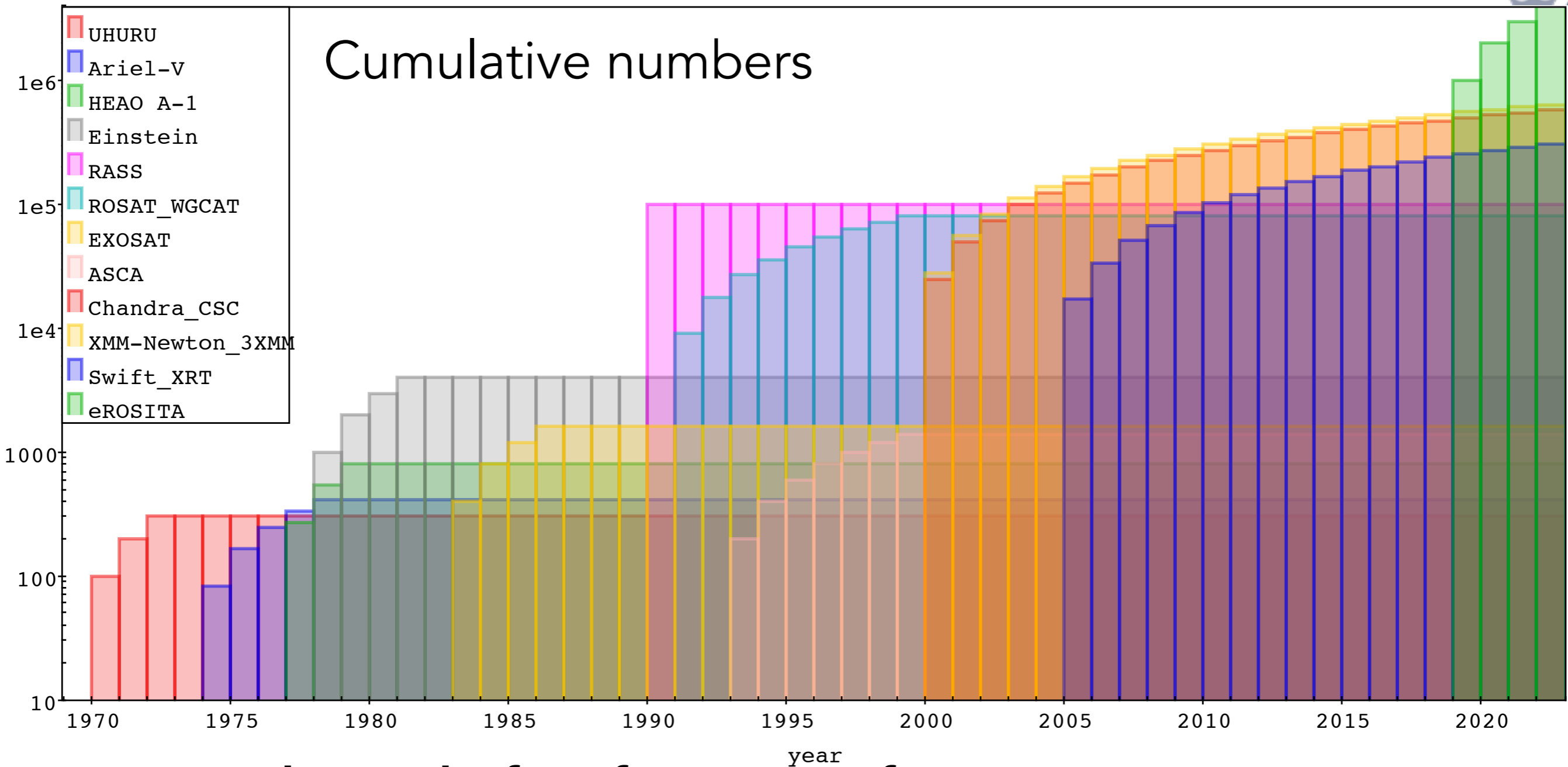
Linear scale!



Approx. Number of X-ray sources detected per year (from published catalogs, not corrected for duplications)



eROSITA surveys in context



At the end of its first year of operations, eROSITA will have detected as many new sources as have been catalogued in 50 years of X-ray astronomy



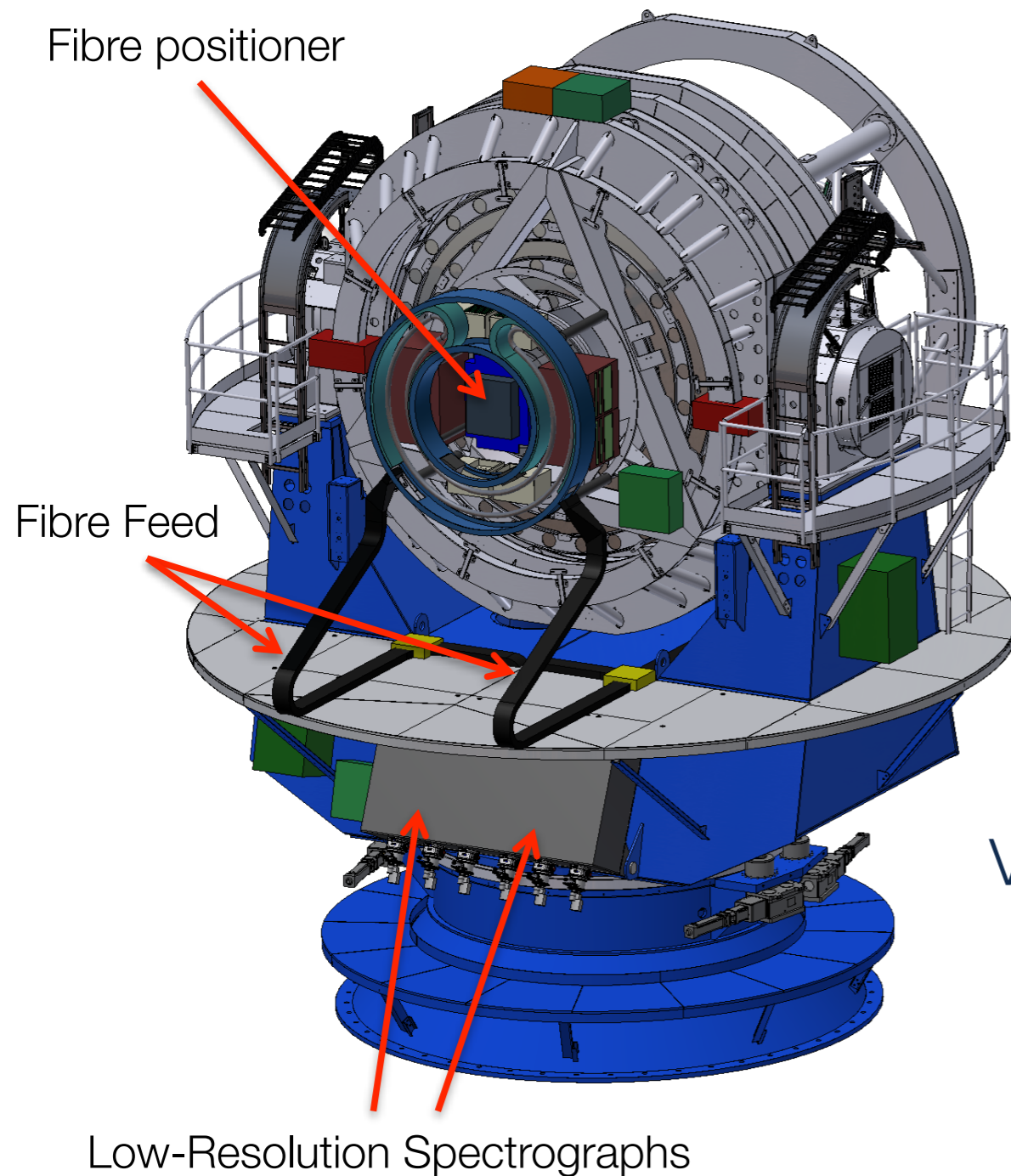
Working with eROSITA



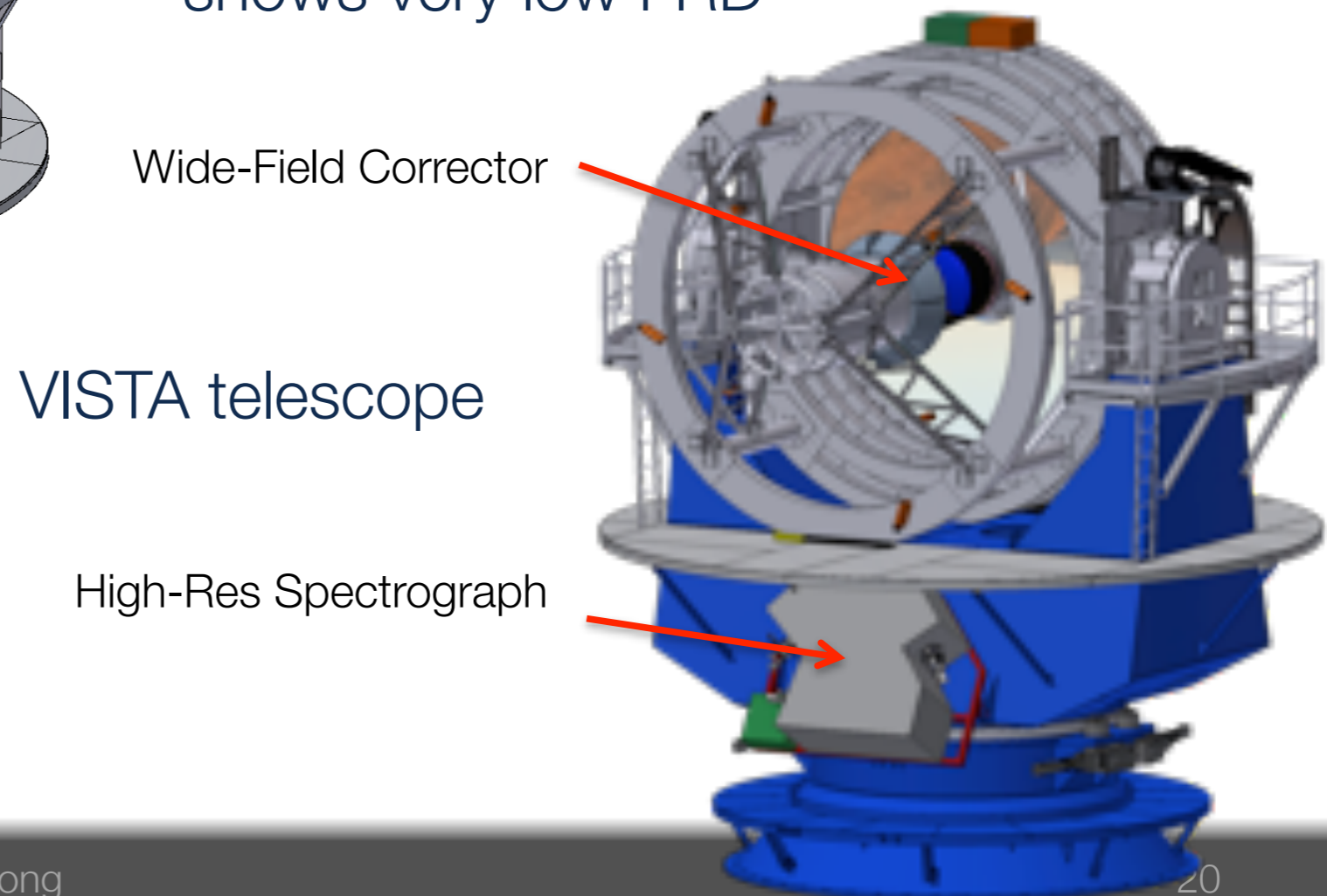
- **eROSITA is a PI instrument**
 - Scientific exploitation of data shared between the partners: 50% MPE and 50% IKI, West/East (gal. coord.)
 - German data public after 2 yrs, 3 releases ('20, '22, '24; **TBC**)
 - Proprietary access via eROSITA_DE (/RU) consortium
 - Projects/papers regulated by working groups
- **Working Groups:**
 - Science: Clusters/Cosmology, AGN, Normal galaxies, Compact objects, Diffuse emission/SNR, Stars, Solar System, Time Domain Astrophysics
 - Infrastructure: Data analysis and catalogues, Multiwavelength follow-up, Calibration, Background
- **Collaboration policy (German Consortium):**
 - Individual External Collaborations (proposal to WGs)
 - Group External Collaborations (team-to-team MoUs)



4MOST instrument overview



- New Wide-field Corrector, fibre positioner and three spectrographs
- Spectrographs mounted on telescope fork (gravitation invariant)
- Short fibre run (~15 m), prototype shows very low FRD



Main science drivers

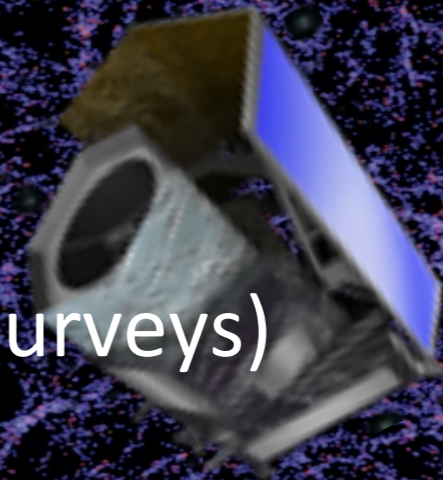
A 5 year 4MOST survey provides



Cosmology and galaxy evolution

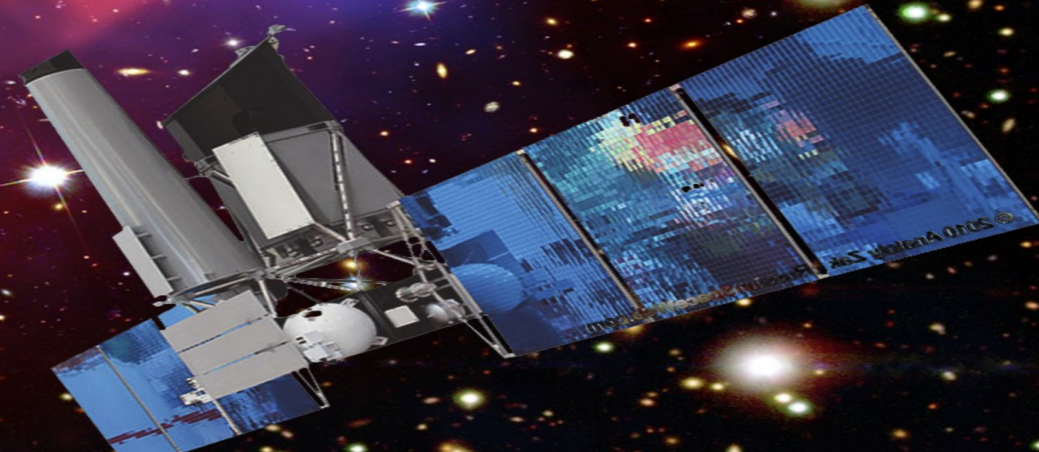
Euclid

VST/VISTA/LSST/SKA (+other all-sky surveys)



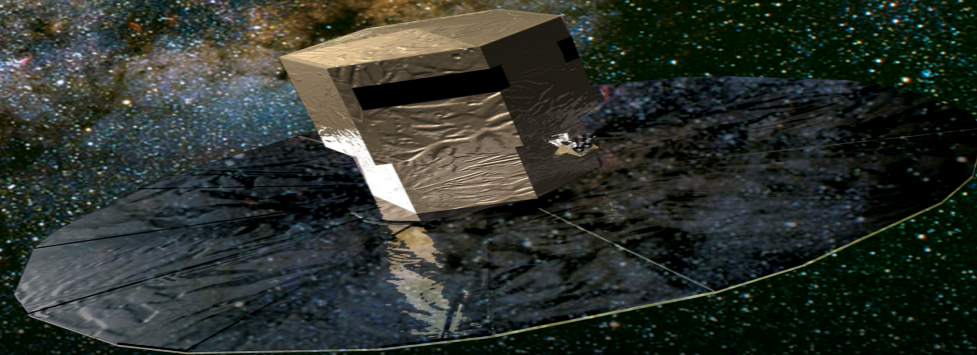
High-energy sky

eROSITA



Galactic Archeology

Gaia



FINALLY, MACHINE LEARNING ESSENTIAL

Radio Galaxy Zoo: compact and extended radio source classification with deep learning

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ABSTRACT

Machine learning techniques have been increasingly useful in astronomical applications over the last few years, for example in the morphological classification of galaxies. Convolutional neural networks have proven to be highly effective in classifying objects in image data. In the context of radio-interferometric imaging in astronomy, we looked for ways to identify multiple components of individual sources. To this effect, we design a convolutional neural network to differentiate between different morphology classes using sources from the Radio Galaxy Zoo (RGZ) citizen science project. In this first step, we focus on exploring the factors that affect the performance of such neural networks, such as the amount of training data, number and nature of layers, and the hyperparameters. We begin with a simple experiment in which we only differentiate between two extreme morphologies, using compact and multiple-component extended sources. We found that a three-convolutional layer architecture yielded very good results, achieving a classification accuracy of 97.4 per cent on a test data set. The same architecture was then tested on a four-class problem where we let the network classify sources into compact and three classes of extended sources, achieving a test accuracy of 93.5 per cent. The best-performing convolutional neural network set-up has been verified against RGZ Data Release 1 where a final test accuracy of 94.8 per cent was obtained, using both original and augmented images. The use of sigma clipping does not offer a significant benefit overall, except in cases with a small number of training images.

Key words: instrumentation: miscellaneous – methods: miscellaneous – techniques: miscellaneous – radio continuum: galaxies.

SUMMARY

- Hamburg has century-long tradition in surveying the sky
- Three lighthouse observational projects: LOFAR, eRosita, 4MOST
- Multi-wavelength large area/volume surveys
- Machine learning/ data science essential