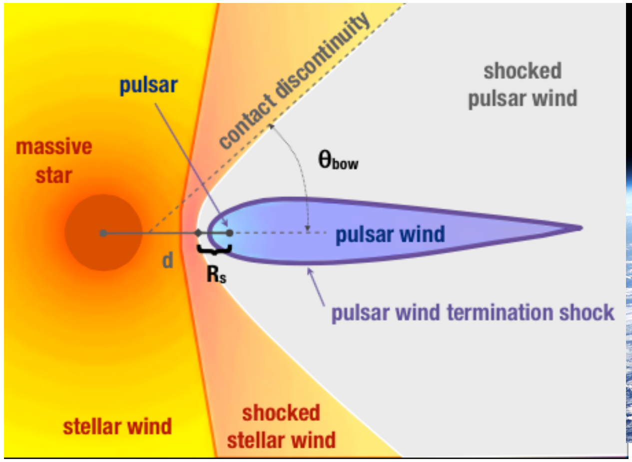
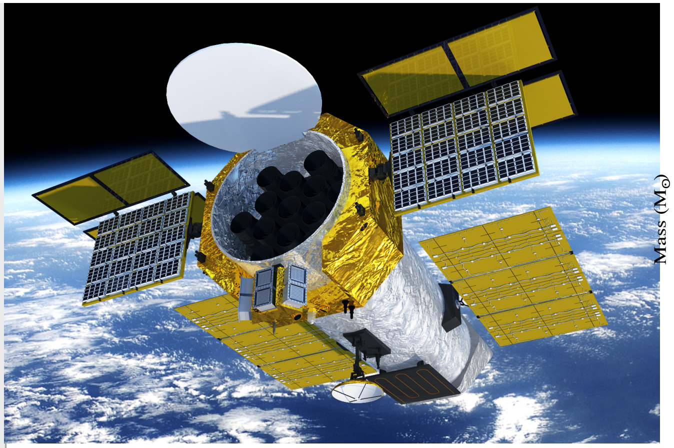
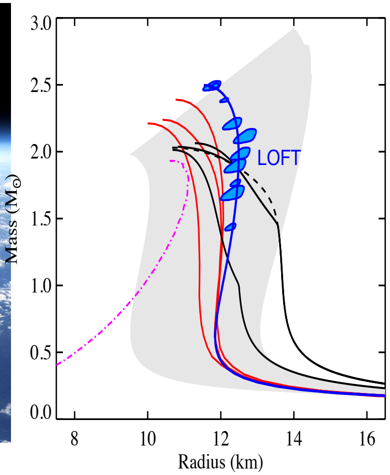
EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

MATHEMATISCH-
NATURWISSENSCHAFTLICHE FAKULTÄT

Institute of Astronomy and Astrophysics







X-rays in the context of cosmic ray science

Andrea Santangelo* IAAT Kepler Center Tübingen
Also at IHEP, CAS, Beijing

Sugar2018, January 23-26 Bruxelles, Belgium

Outline

- The talk is divided in two parts:

Part I: The keV - cosmic rays connection (What can we learn on cosmic rays from X-rays…)

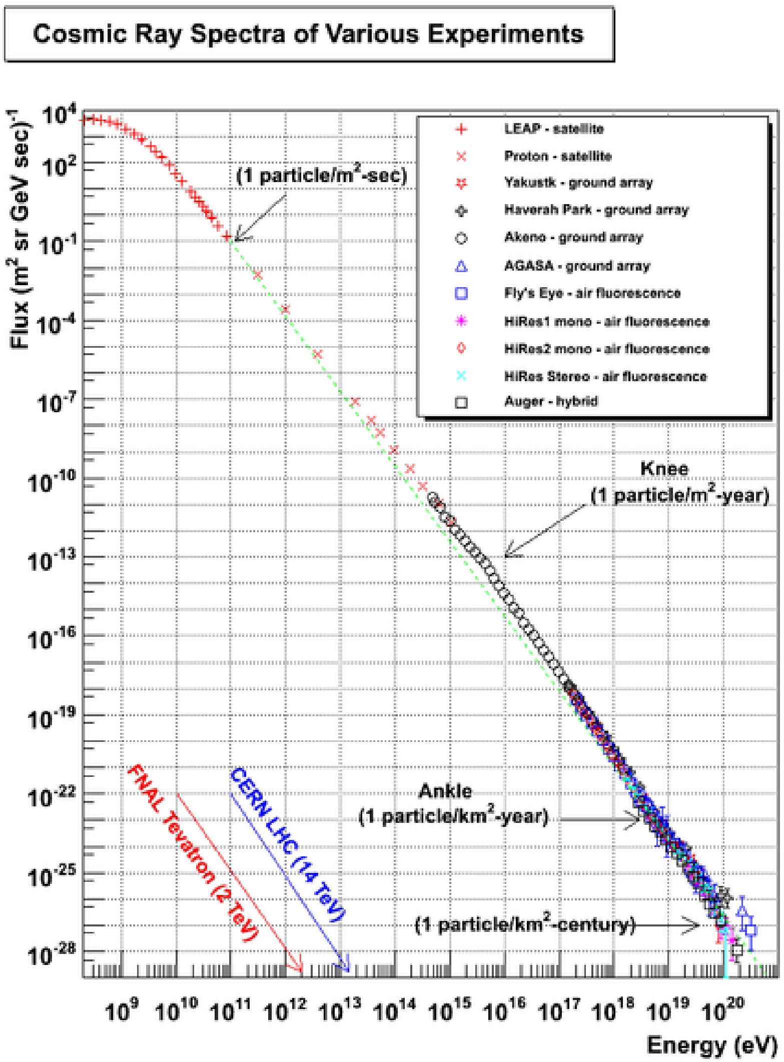
Part II: The near and long- term future in X-rays (missions and their “agenda”)

Part I

The X-rays – Cosmic Rays *connection*

Or better the keV – TeV connection

A preliminary question: Why Gamma-rays?

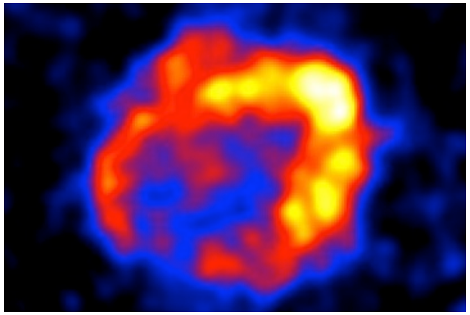


- **Central question: the Origin of Cosmic Rays**
  - Acceleration Mechanism
  - Sources of Cosmic Rays up to the knee (Galactic Origin)
- **Gamma-rays as messengers of the High Energy processes**
  - Proof of particle acceleration beyond TeV
  - Mapping of acceleration and propagation sites
  - Direct tracers of relativistic particle populations

Observing the non-thermal Universe

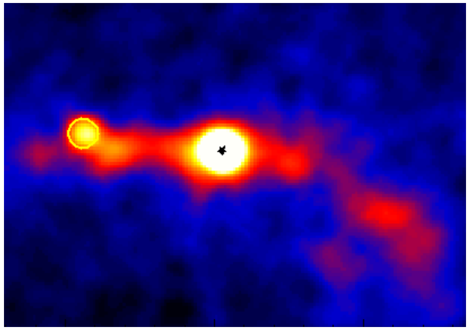
The puzzle of the origin of cosmic rays

Search for Galactic Cosmic Rays **accelerators**



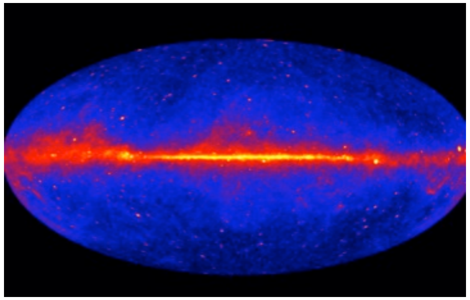
acceleration

Understanding CR **escape into the ISM**



escape = injection into ISM

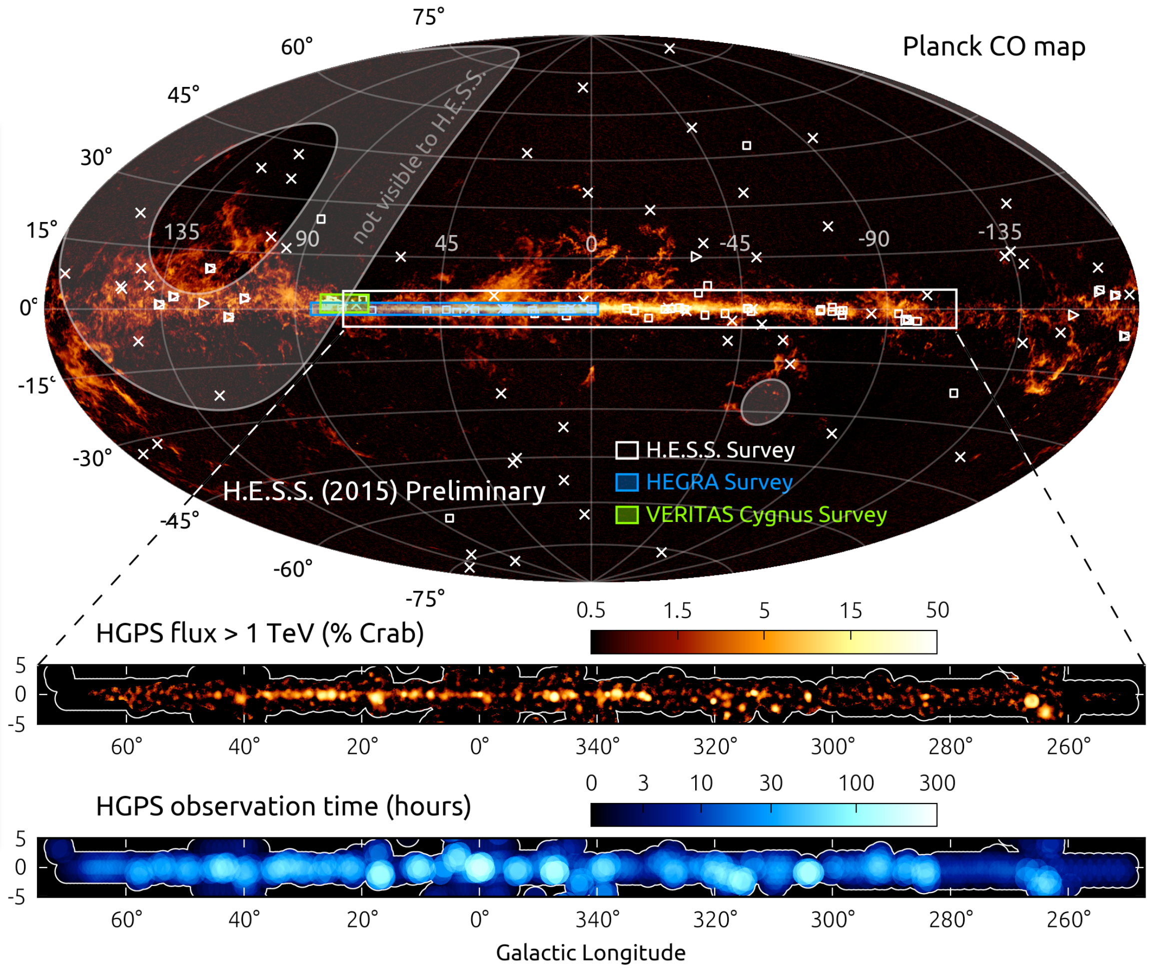
Big Puzzle:
Factories of 10^{15} eV particles
PeVatrons (CR accelerators can accelerate/confine PeV particles for short amounts of time)



diffusing and filling the Galaxy

H.E.S.S. galactic plane survey

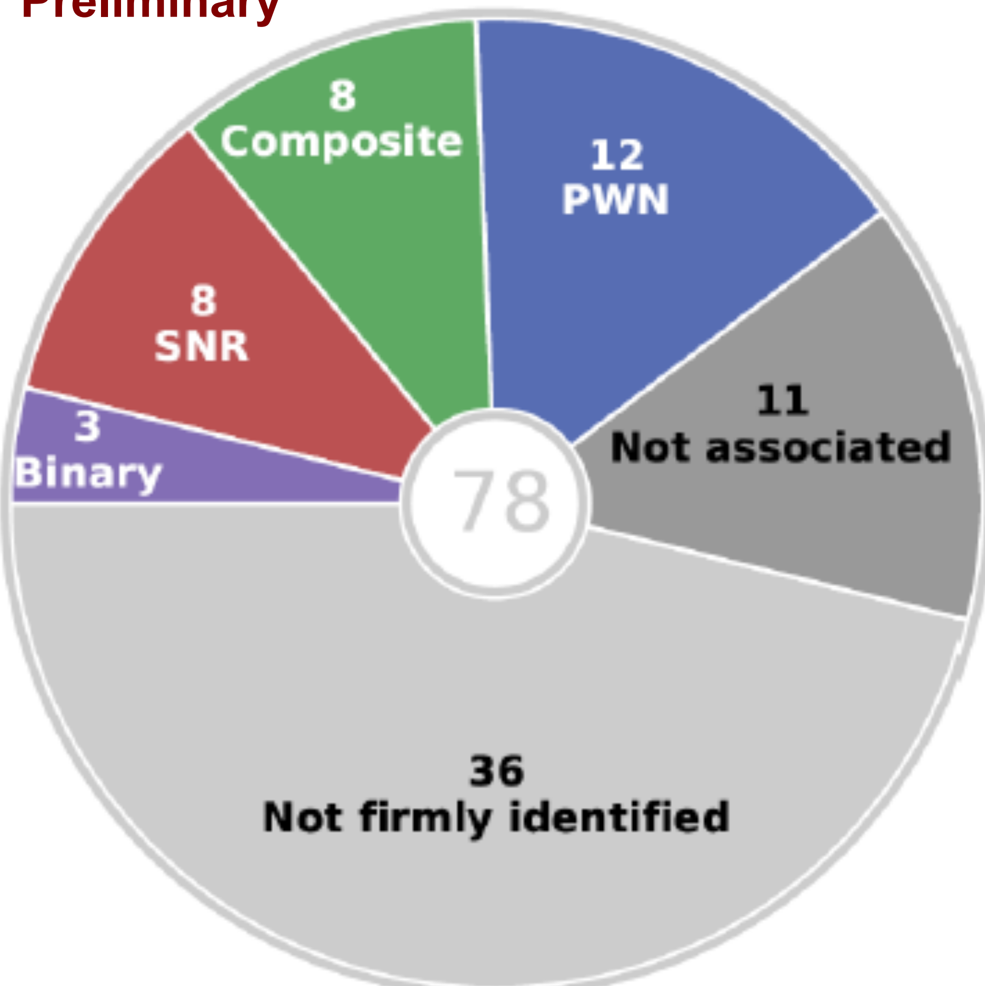
- H.E.S.S. I telescope system (CT1 – CT4)
- **2673 hours** of (good quality) observations,
  years 2004-2013
- $-110° < l < 65°$
  $-3.5° < b < 3.5°$
- 0.2-100 TeV, $R_{68\%}$ ~ 0.07°
- Inhomogeneous exposure (sources of particular interest included)



H.E.S.S. Collaboration, H. Abdalla et al. accepted, A&A (2018)

Census of the HGPS catalogue

Preliminary



Not only Supernovae:
Some of the **10+ classes of objects** found to be galactic or extragalactic accelerators)

→

The "local fog" of Galactic Cosmic rays

X-rays needed to identify counterparts for e.g. CTA sources!

keV – TeV connection (1)

synchrotron X-rays of directly accelerated electrons –
A tool for probing Cosmic TeVatrons:
SNRs, Pulsar Wind Nebulae, gamma-ray loud binaries, AGN/ Blazars, … a tool for probing diffusion

Req. Broad band in the X-rays!

↓

Thermal emission also

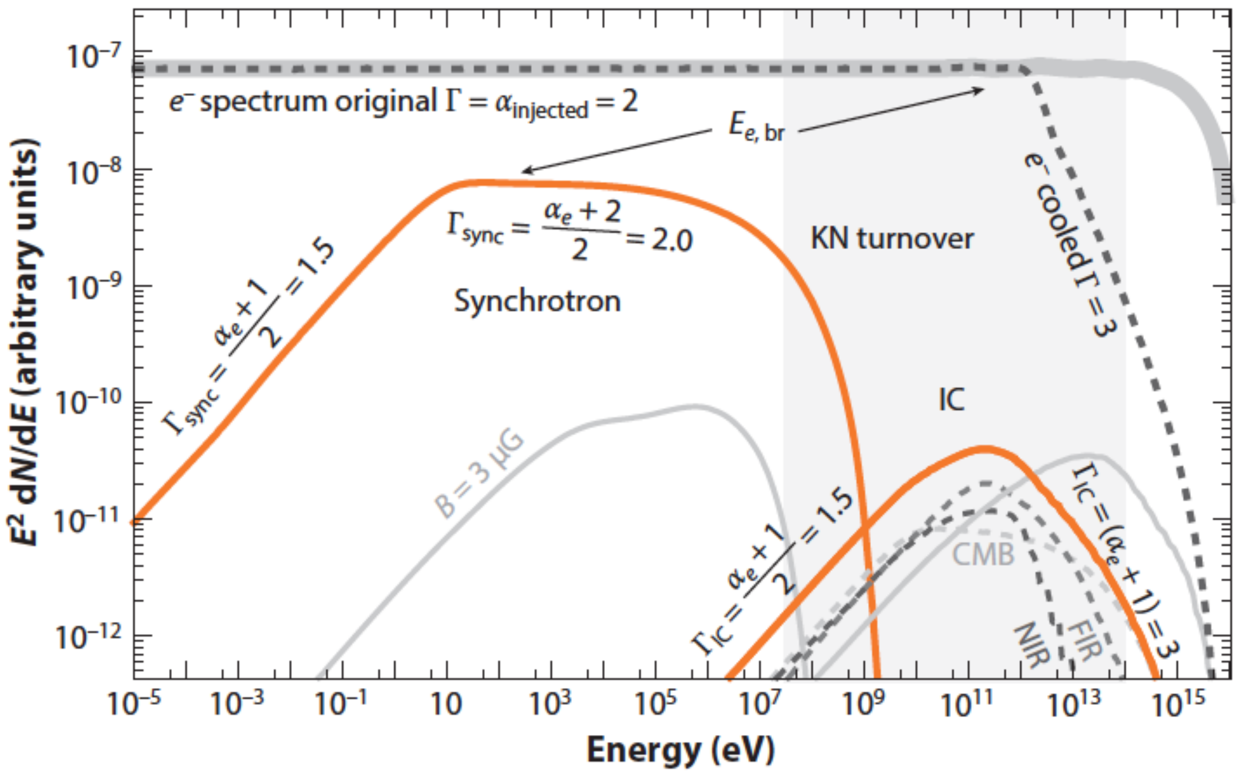


Figure from the review by S. Funk (Ann. Rev. Nucl. Part. Sci., 2015)

keV – TeV connection (2)

synchrotron X-rays of secondary electrons –
A tool, complementary to TeV (and neutrinos…) for not yet discovered PeVatrons and even higher energy-trons…

Req. Broad band in the X-rays and sensitivity.

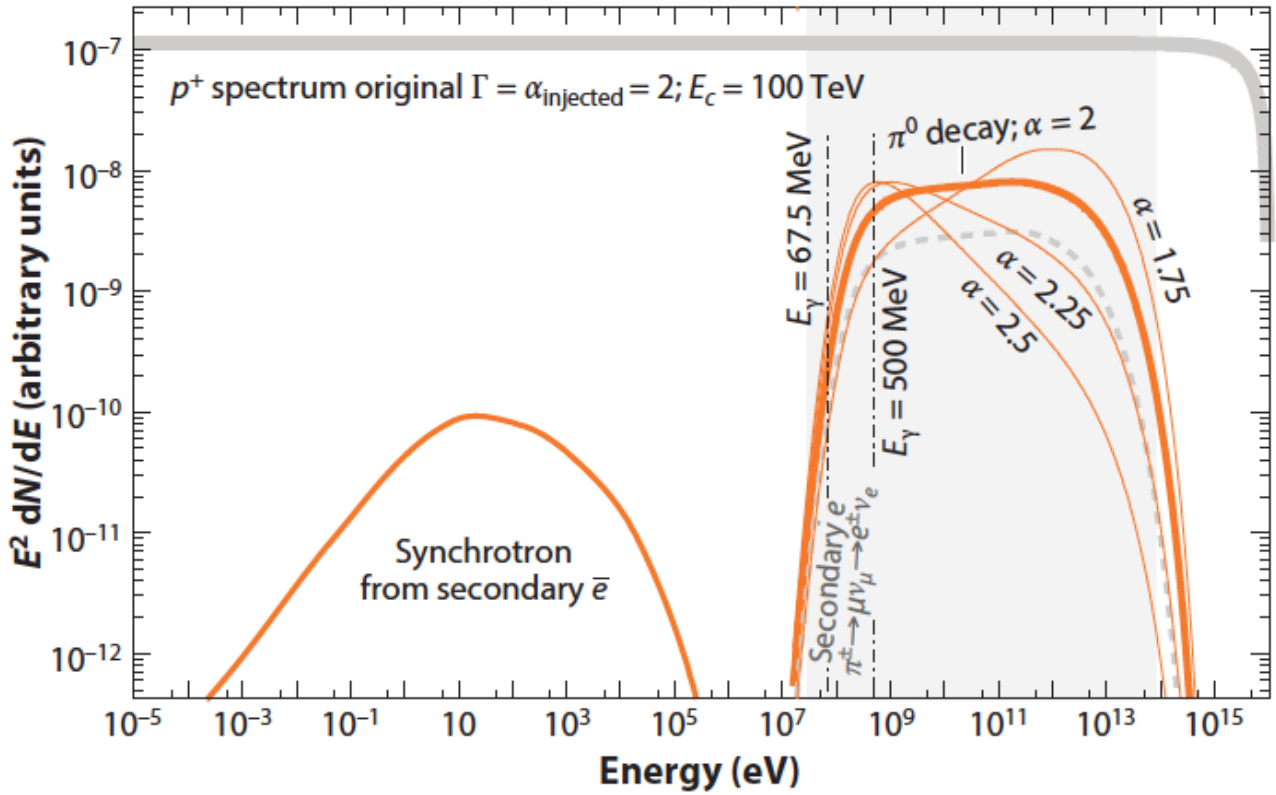


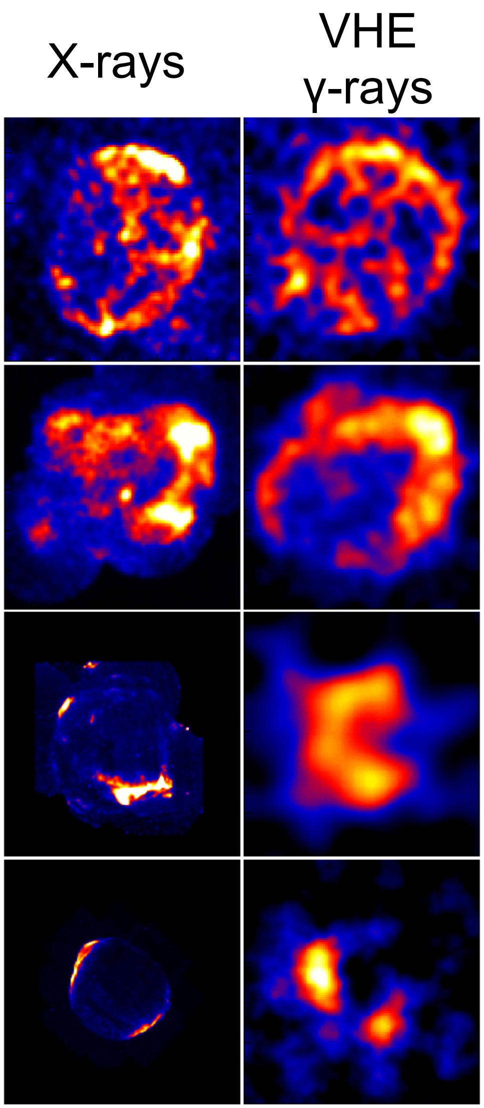
Figure from the already cited review by S. Funk (2015)

Gamma-ray emitting SNRs

- **Young, historical supernovae, in different evolutionary stages → SNRs can be pevatrons during a (very short time)**
  - **inverse Compton of the population emitting non thermal X-rays**

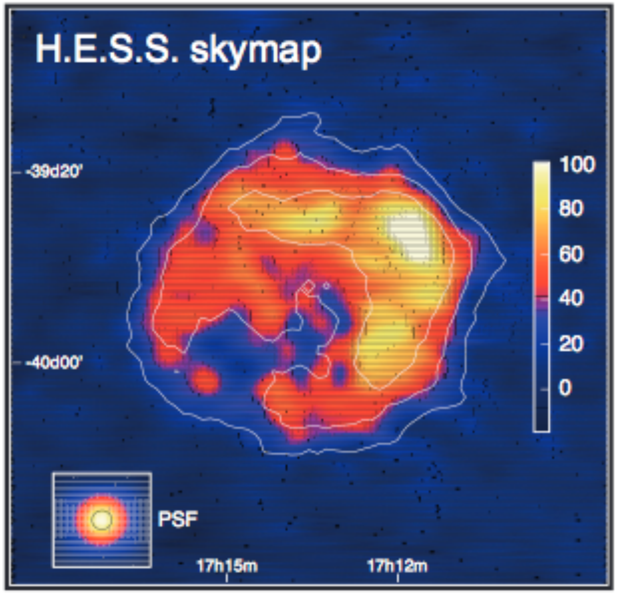
- **More evolved SNRs proven to accelerate protons**
  - **In interaction with molecular clouds**
  - **π^0 bump in Fermi-LAT**

How X-rays could help in understanding propagation and acceleration?

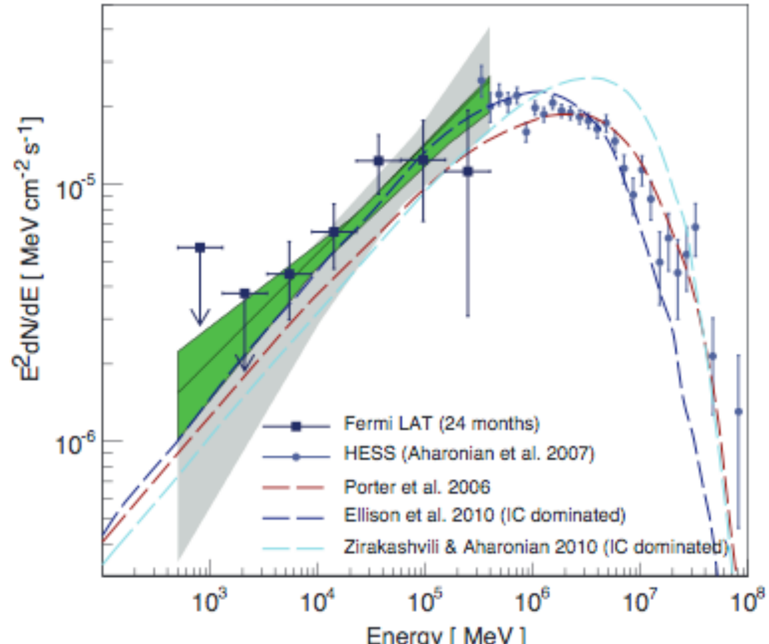


RX J1713: First Shell-type SNR

…observed in TeV Gamma-rays!



H.E.S.S. collaboration 2004



Fermi-LAT collaboration 2011

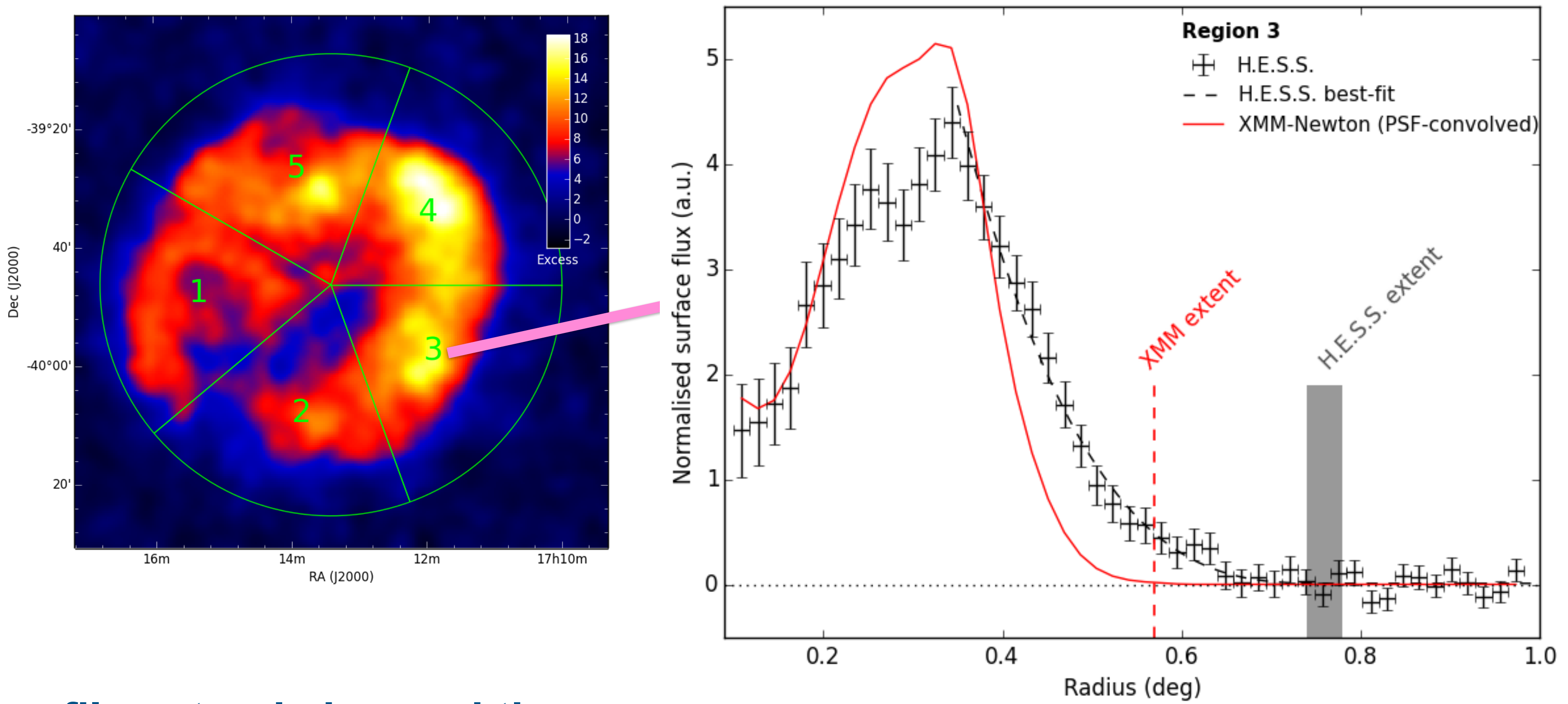
Spectral cut-off shape? → *Protons vs. electrons*

Spatially resolved spectra? → *physical properties*

Morphology & Radial profiles + comparison with X-rays → *particle diffusion+ escape?*

Watching CRs escaping into ISM?

High precision measurements of RX J1713-3946

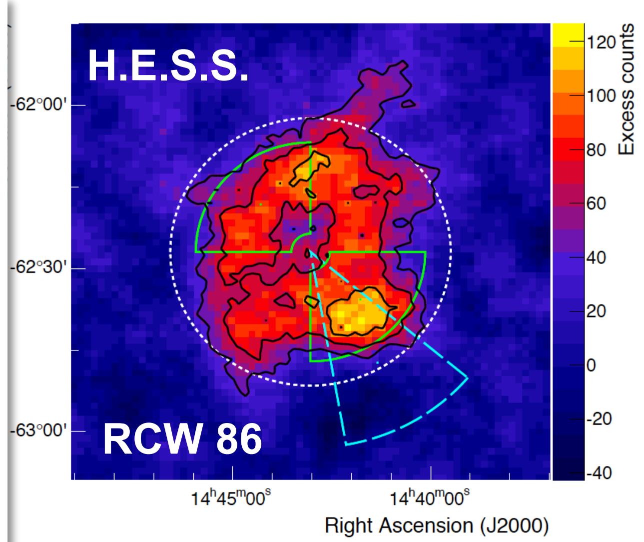


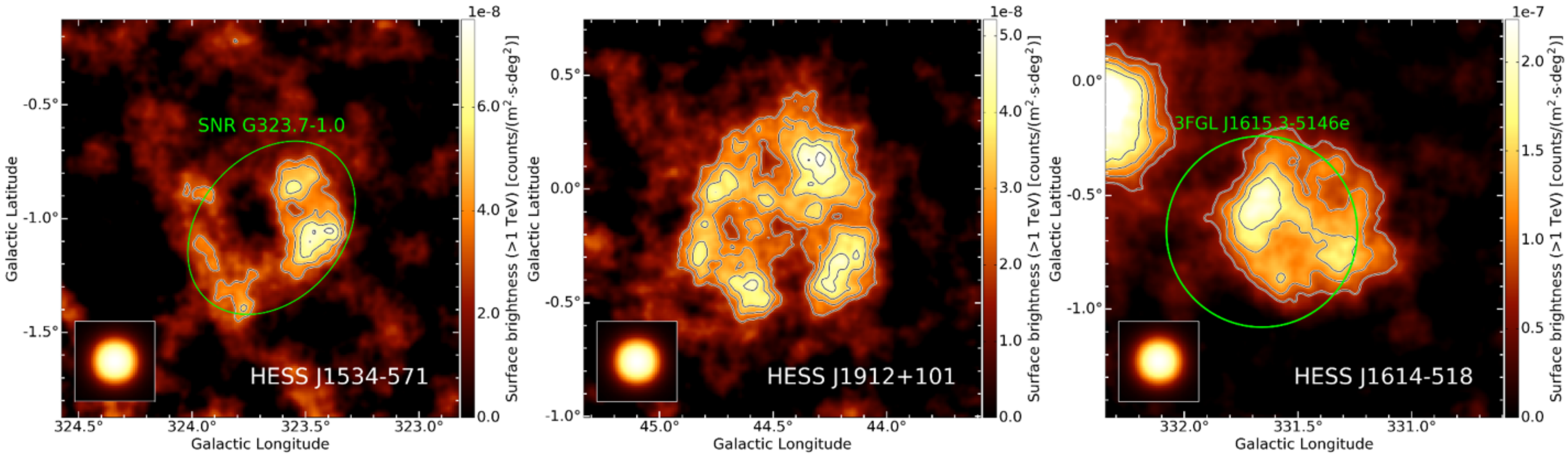
TeV profile extends beyond the X-Ray emission in some regions→ *particle escape in interaction with denser regions of the surrounding medium? Or B-field evolution explains faster X-ray emission drop?*

H.E.S.S. collaboration accepted A&A, 2018

New shell-type SNRs with H.E.S.S.

- **RCW 86:**
  deep exposure confirms TeV shell appearance
  - Good correlation between TeV and hard X-ray (IC vs. synchrotron), likely leptonic dominated, B ~20 μG
  - Maximum energy ~ 3 TeV
- **New TeV shells:**
  HESS J1534-571, HESS J1614-518, HESS J1912+101
  - Identified in the HESS Galactic Plane Survey (HGPS) data set
  - HESS J1912+101 likely the only TeV SNR w/o counterparts in other wavebands
  - Lack of nonthermal X-ray synchrotron emission (at least for HESS J1534-571): hints at proton emission (?)





H.E.S.S. collaboration accepted A&A, 2018

Pevatrons and acceleration

Young SNRs are perfect laboratories to study *particle acceleration* and and *magnetic field amplification*

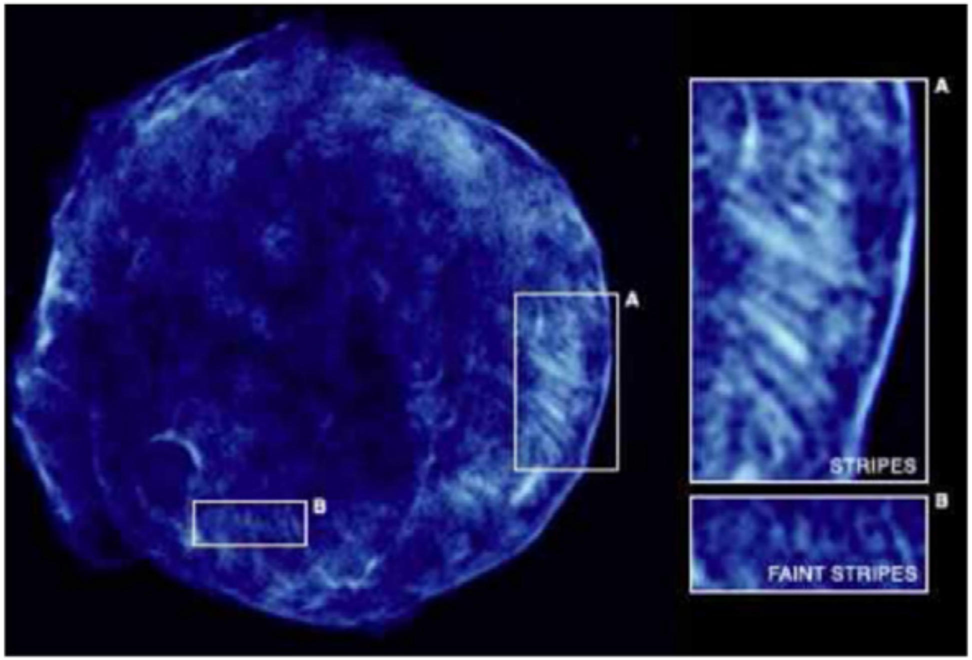
Acceleration efficiency: fraction of available energy converted to nonthermal particles in SNRs, in PWNe and AGN) → essential for understanding **Diffusive Shock Acceleration**

Maximum possible energy achieved by individual particles

Magnetic Field Amplification (in strong non-linear shock) due to cosmic ray pressure

A robust program in X-rays (1)

Magnetic Field amplification



Deep Chandra 4–6 keV image **of Tycho's SNR.** Bright features are due to synchrotron radiation produced by multi-TeV electrons.

"Stripes" of Synchrotron emission are signature of MFA.

Magnetic fields of about **0.1 mG**
If due to rapid synchrotron cooling or fast magnetic field damping.

Also **year-scale time variability** of synchrotron X-ray filaments might suggests fields up to **1 mG** (synchrotron cooling time) or 0.1 mG for intermittent turbolent magnetic fields.

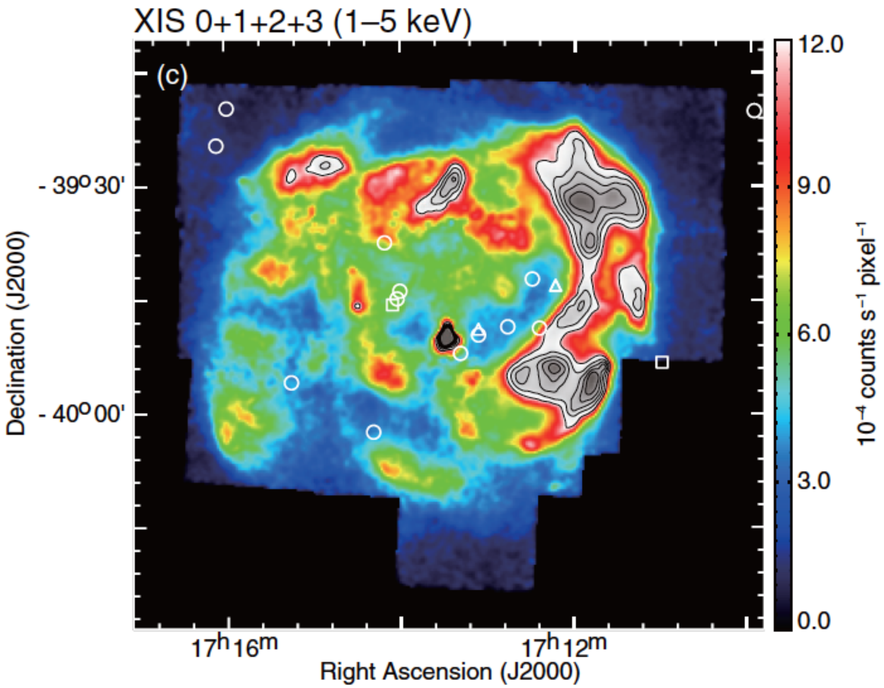
Aharonian et al, 2014 (ASTRO-H White Paper)

Eriksen et al, 2011

Req. Excellent Angular resolution!

A robust program in X-rays (2)

Synchrotron dominated SNRs



Suzaku image (1–5 keV) of **SNR RX J1713.7-3946**: X-ray emission is completely dominated by synchrotron radiation.

See also Vela Jr., HESS 1731 -347

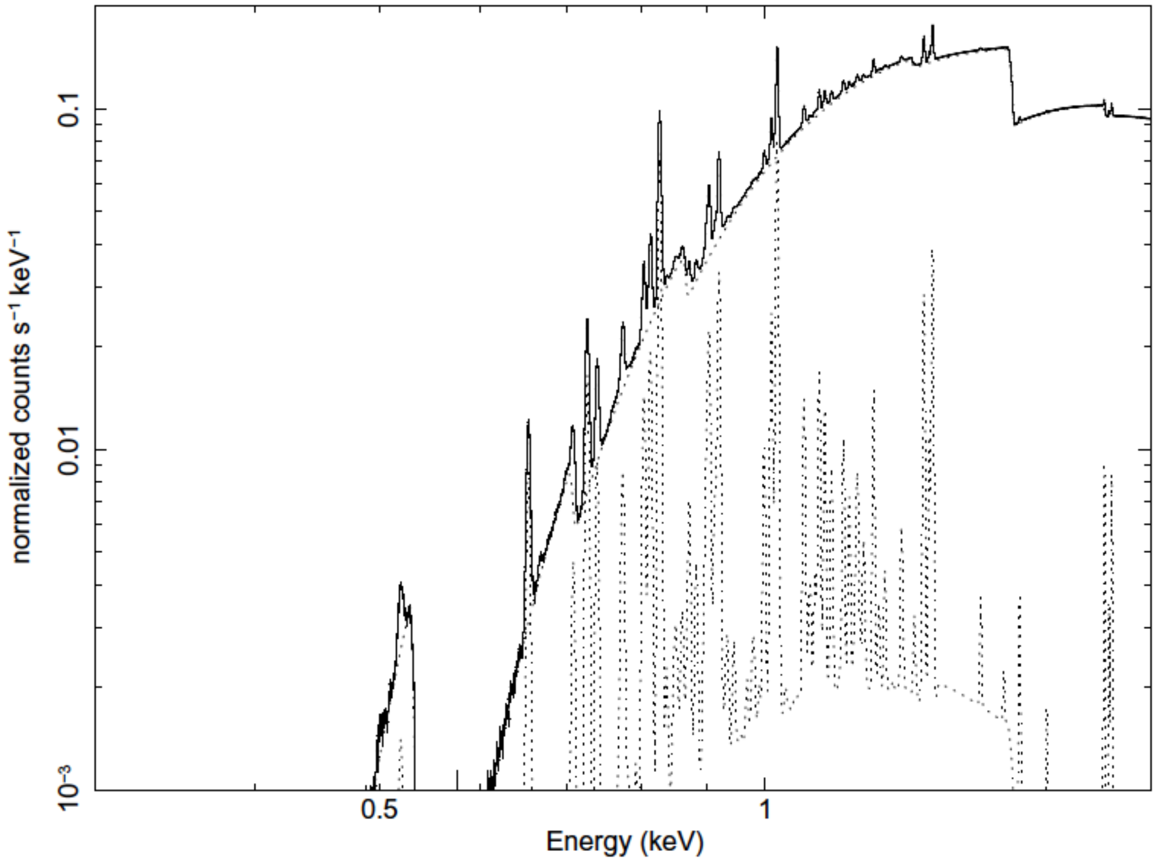
Many of these sources **have a CCO**, suggested to be core collapse SNae, occurring in the low density medium blown by the stellar wind before the explosion.

The **search for thermal emission** from such SNRs (powerful accelerators) is essential to understand the background thermal plasma.

Req. What is needed is the superior energy resolution → **Hitomi**

Sano et al., 2013

A simulation



Simulation of ASTRO-H 100 ks observation of the RX J1713−3946 northwestern limb

Thermal lines would have been detected thanks to the **Hitomi calorimeter** (energy resolution of several eV).

A. Bamba, 2014

Lines and the energy of accelerated plasma

Rankine-Hugoniot relation

$$kT = \frac{2(\gamma - 1)}{(\gamma + 1)^2} \mu v_s^2$$

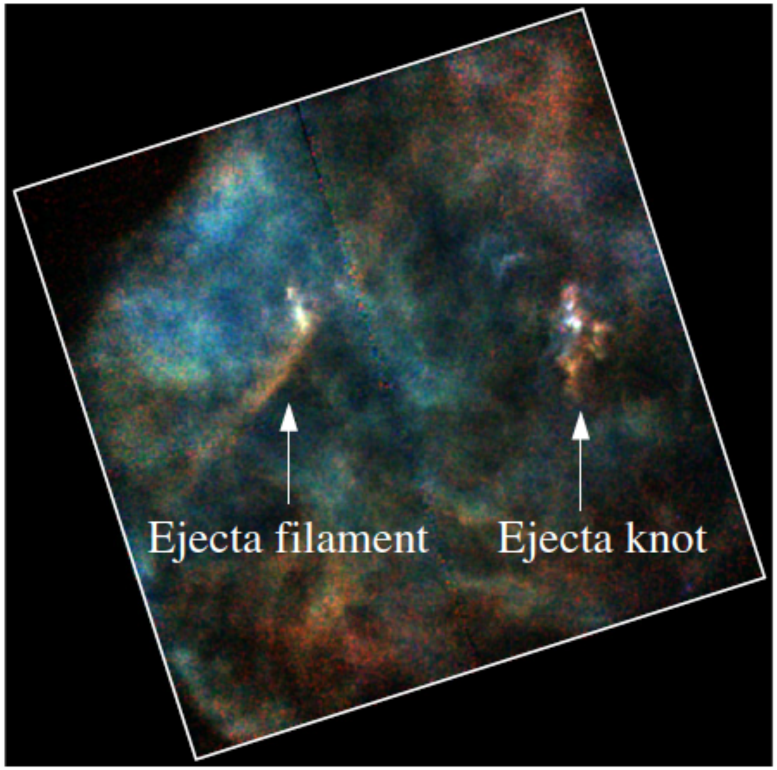
Relating **the kinetic energy of the shock** to the **thermal energy of the downstream plasma**

Study of the Oxygen lines with the XMM-Newton gratings has shown:

1) doppler shift of the line (1500 km s^{-1})

2.) thermal broadening much less than expected → 30 keV

An X-ray microcalorimeter would enable this study for **several elements and for diffuse emission**



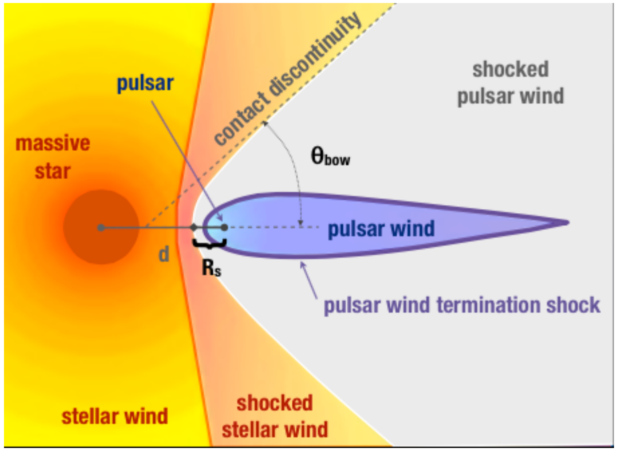
PuppisA, Katsuda et al., 2013

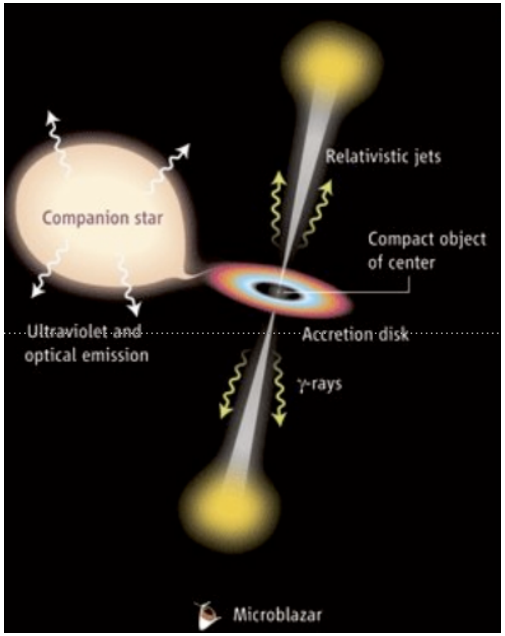
TeV Gamma Ray Binaries

- Gamma-ray binaries: small class of objects

	Period (days)	$M_*(M_\odot)$
PSR B1259-63	1236	31
LS 5039	3.9	23
LS I +61 303	26.4	12
HESS J0632+057	315	16
1FGL J1018.6-5856	16.6	31

- Accretion/ejection in binary systems
- Anisotropic radiation fields (absorption by pair creation)

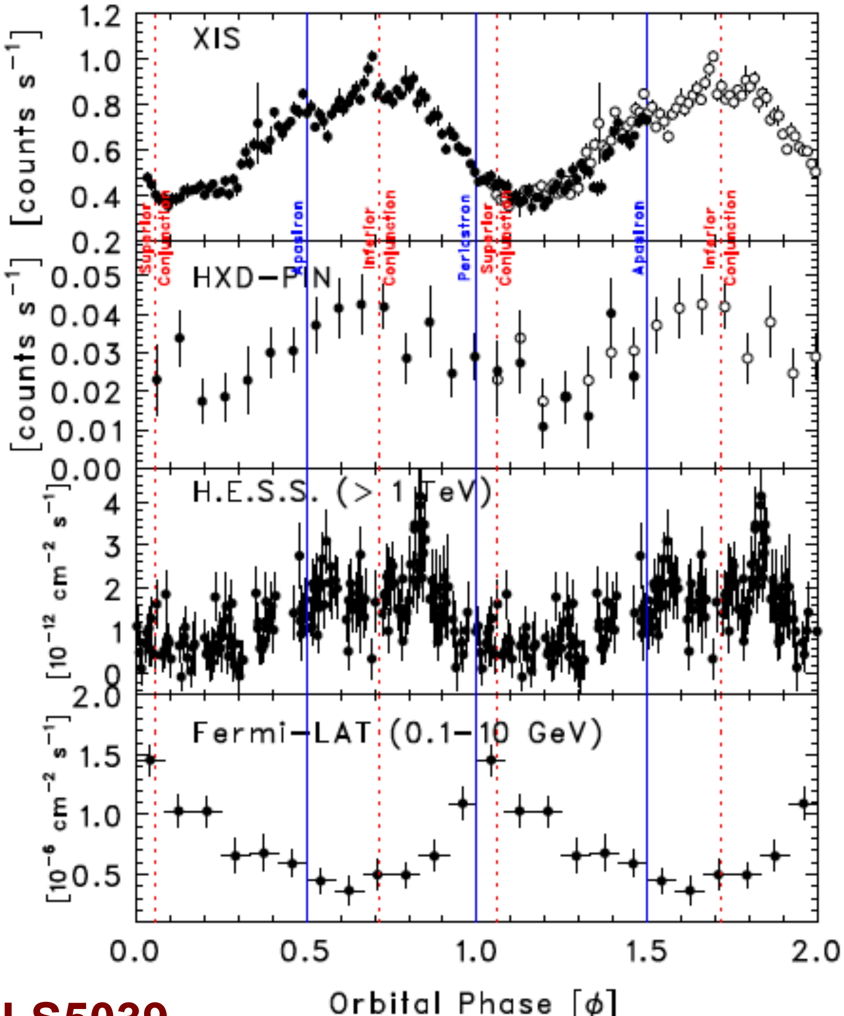




G. Dubus, ArXiv: 1307.7083

A new kid in town: +HESS1832-093?

Orbital studies of Gamma Binaries



LS5039

X-rays→ most likely synchrotron

TeV → inverse Compton + pair production absorption in the stellar wind

GeV → unaffected by pair production absorption (second population?)

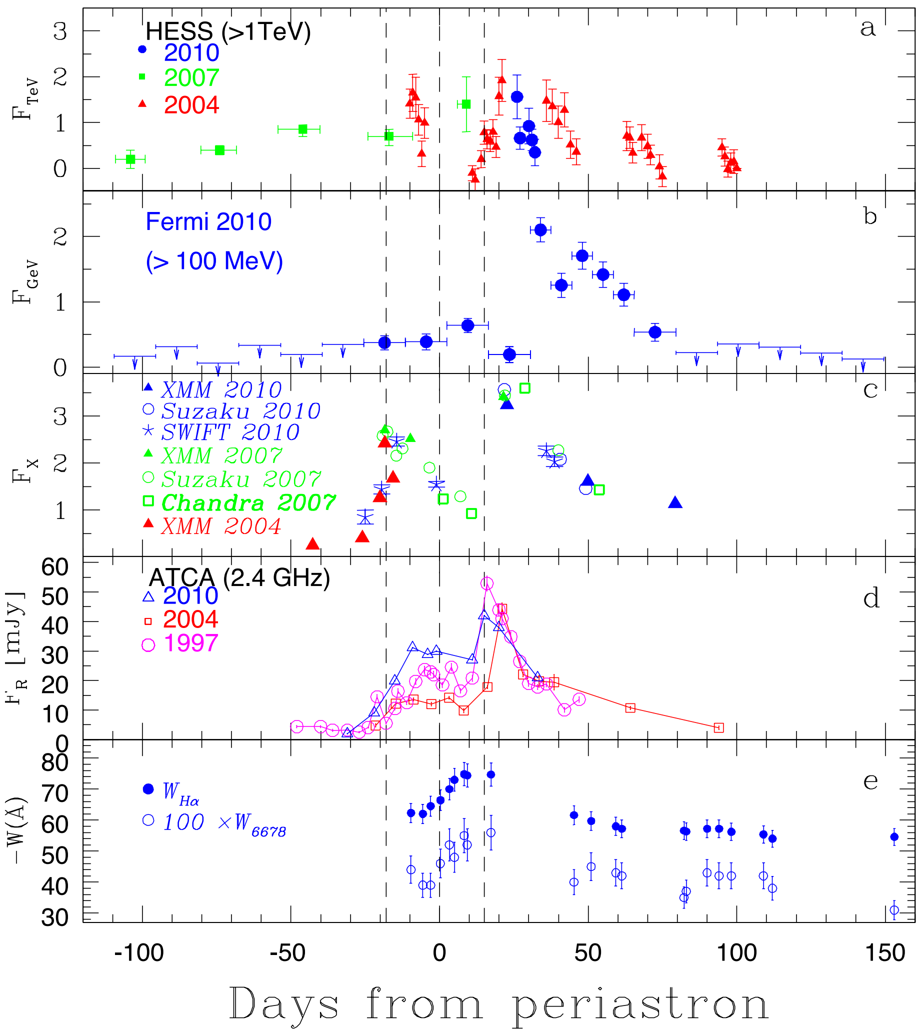
acceleration of TeV electrons on timescales of seconds?

In the future: **Orbital Phase resolved spectroscopy at TeV!**

X-ray Polarimetry could confirm the synchrotron nature of emission

Suzaku + HESS + Fermi (Takahashi et al. 2009)

PSR B1259-63: a pulsar Gamma-ray binary



Pulsar (P 48ms, L_{sd}= 8 ×10^{35} erg/s) + O9.5Ve star (L_{star}= 2.3 × 10^{38} erg/s) + circ. Disk

Binary system: D = 2.3, P_{orb}= 3.4 years, eccentricity = 0.87, orbital inclination i ~24°

Variable/periodic emission in radio, optical, X-rays, GeV and TeV γ-rays

Pulsations seen only in radio (and away from periastron)

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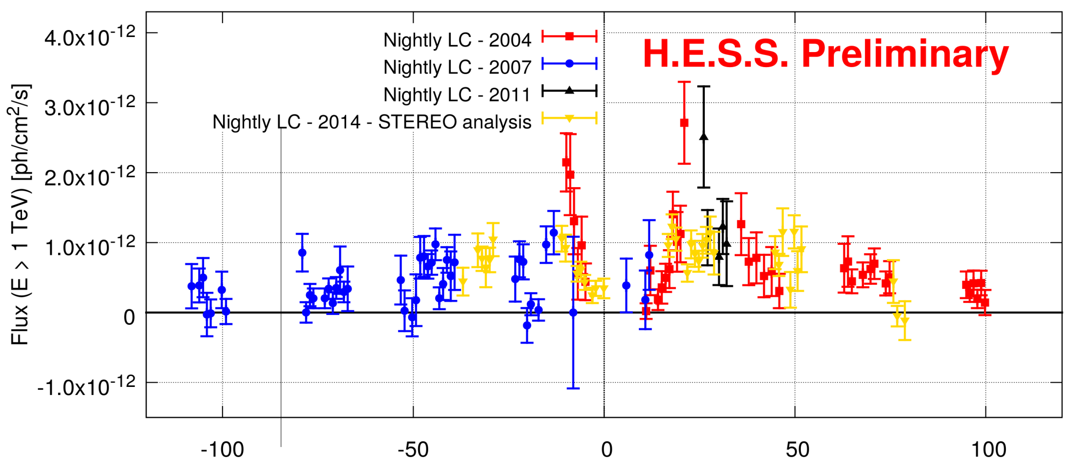
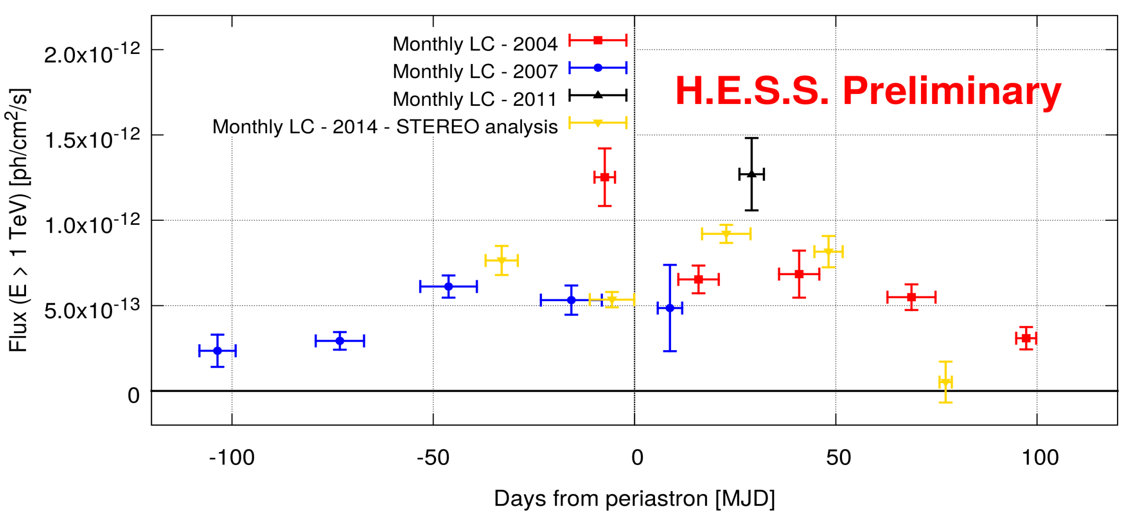
Periastron passage 2014

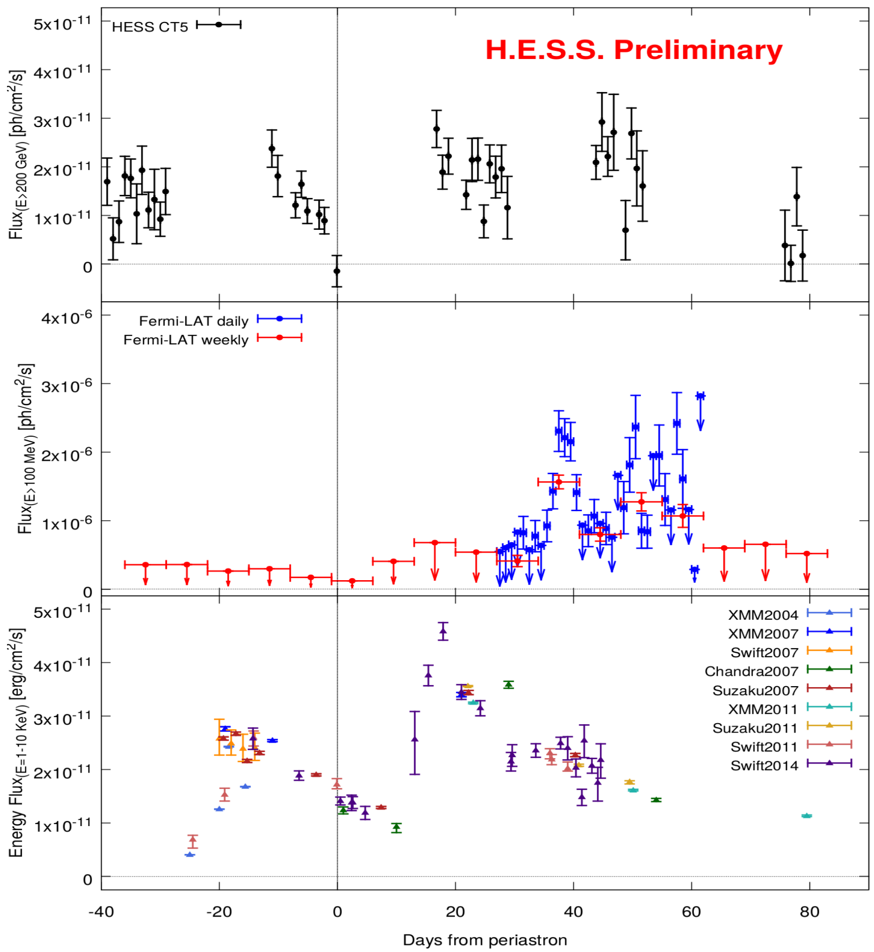




- **confirmed double-peak pattern** observed in the long-term light curve
- **Local minimum at the periastron passage**
- **Source still active at VHEs at 40-50 days after periastron**
- Differences between light curves w.r.t previous periastron events

57 hrs, Source detected at 40σ level, MW campaign

Muli-frequency observations



H.E.S.S. collaboration in prep. (2018)

- Comparison of results from H.E.S.S., Fermi-LAT and Swift-XRT simultaneous observations
- **X-rays: highest-ever flux recorded** in 2014 (2nd disk crossing). Hints of variability during GeV flare?
- **Fermi-LAT: reappearance of the gamma-ray flare** (slight differences), marked variability
- **H.E.S.S. (CT5): high emission state at VHEs** during the GeV flare

Chernyakova et al., 2015

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Part II

The „X-ray future“: Missions and ther agenda

The future is bright…

- *What comes next in X-ray astrophysics?*

- **Part II.I:** ***near term*** **→ eROSITA, (2018)**
  - Mapping the hot Universe
- **Part II.II**: ***mid-term*** **→ *eXTP* (2024)**
  - Physics and Astrophysics of bright sources
- **Part II.III**: ***long-term*** **→ *ATHENA* (2028)**
  - *The deep hot and energetic Universe*

Parenthesis: Opening X-ray polarimetry (IXPE, XIPE).

Part II.1

eRosita

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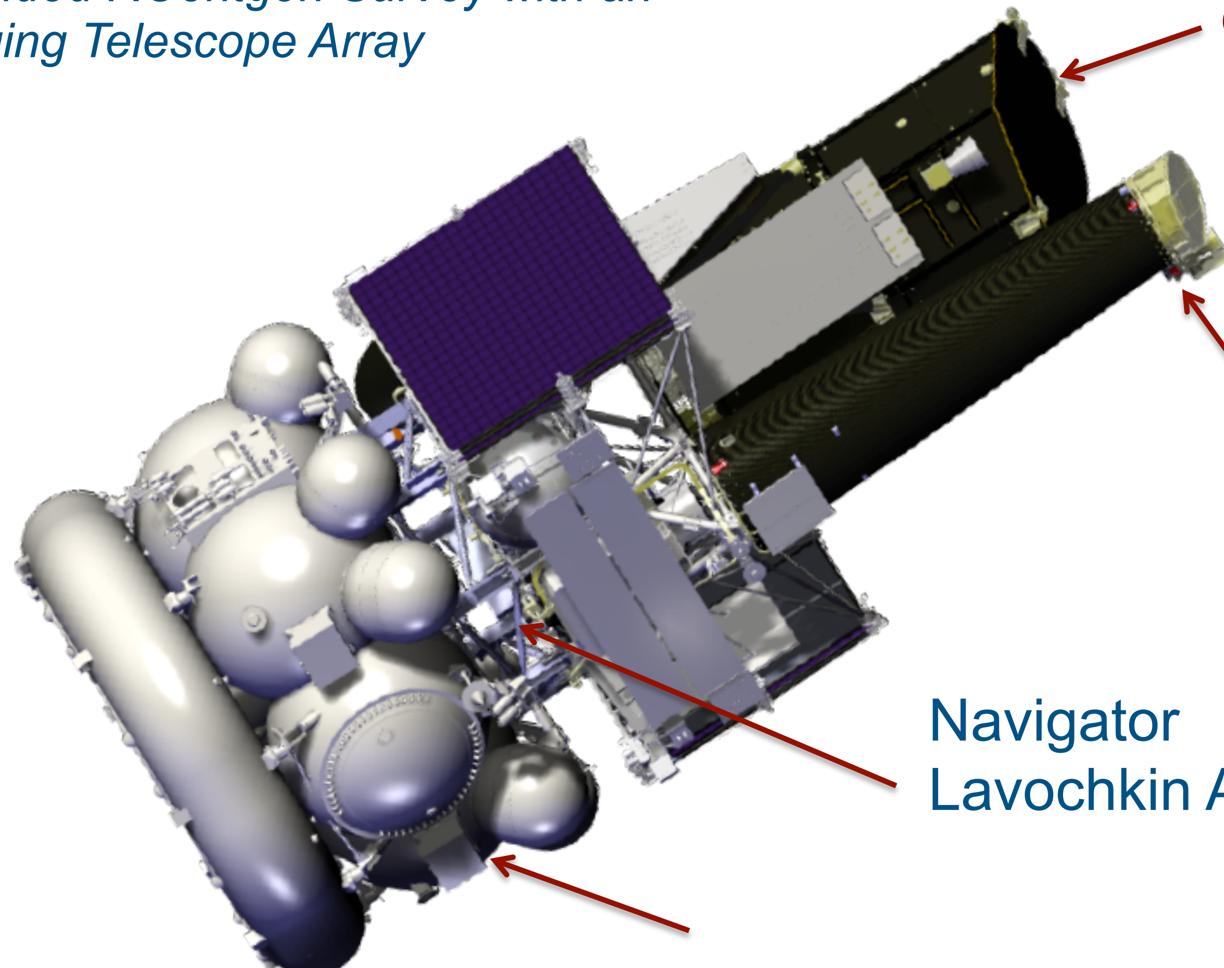
Soon to come: Spectrum X-Gamma

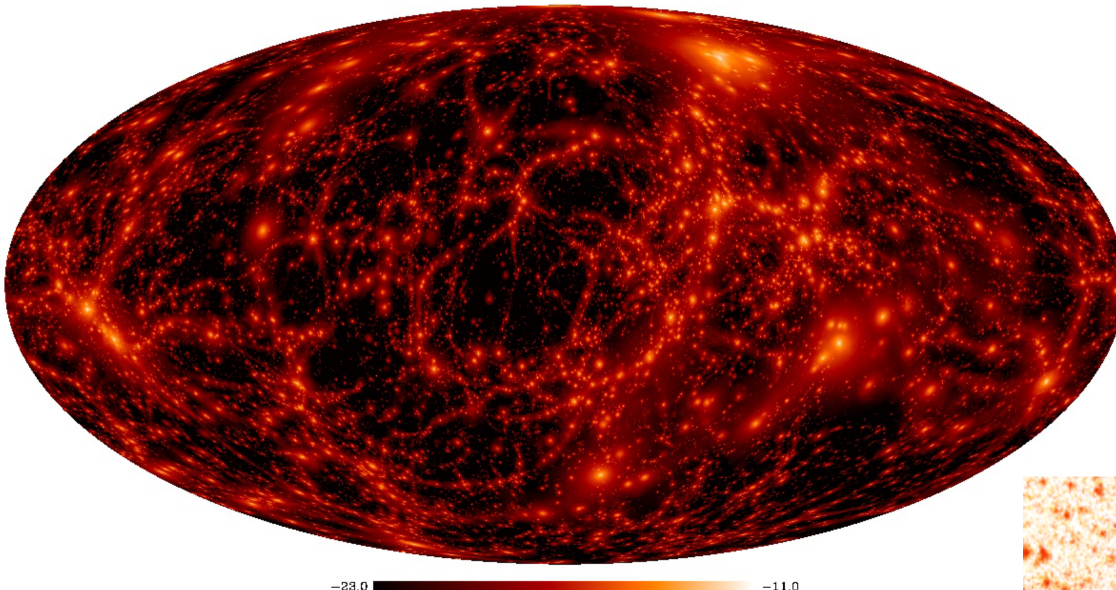
extended ROentgen Survey with an Imaging Telescope Array



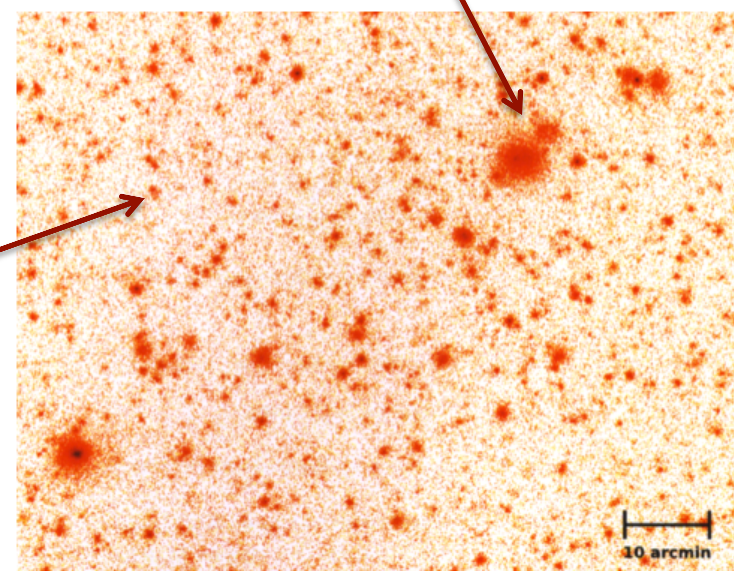
+ Launcher
+ Ground segment

Planned to be launched in Autumn 2018

2018: Mapping the hot Universe



Diffuse X-ray emission traces the massive knots of the cosmic web: **Cluster of Galaxies**



Point sources signpost the growth of SM Black Holes: **Active Galactic Nuclei**

Growth of structure → cosmological constrains

eRosita will detect 10^5 Clusters and $3x10^6$ AGNs

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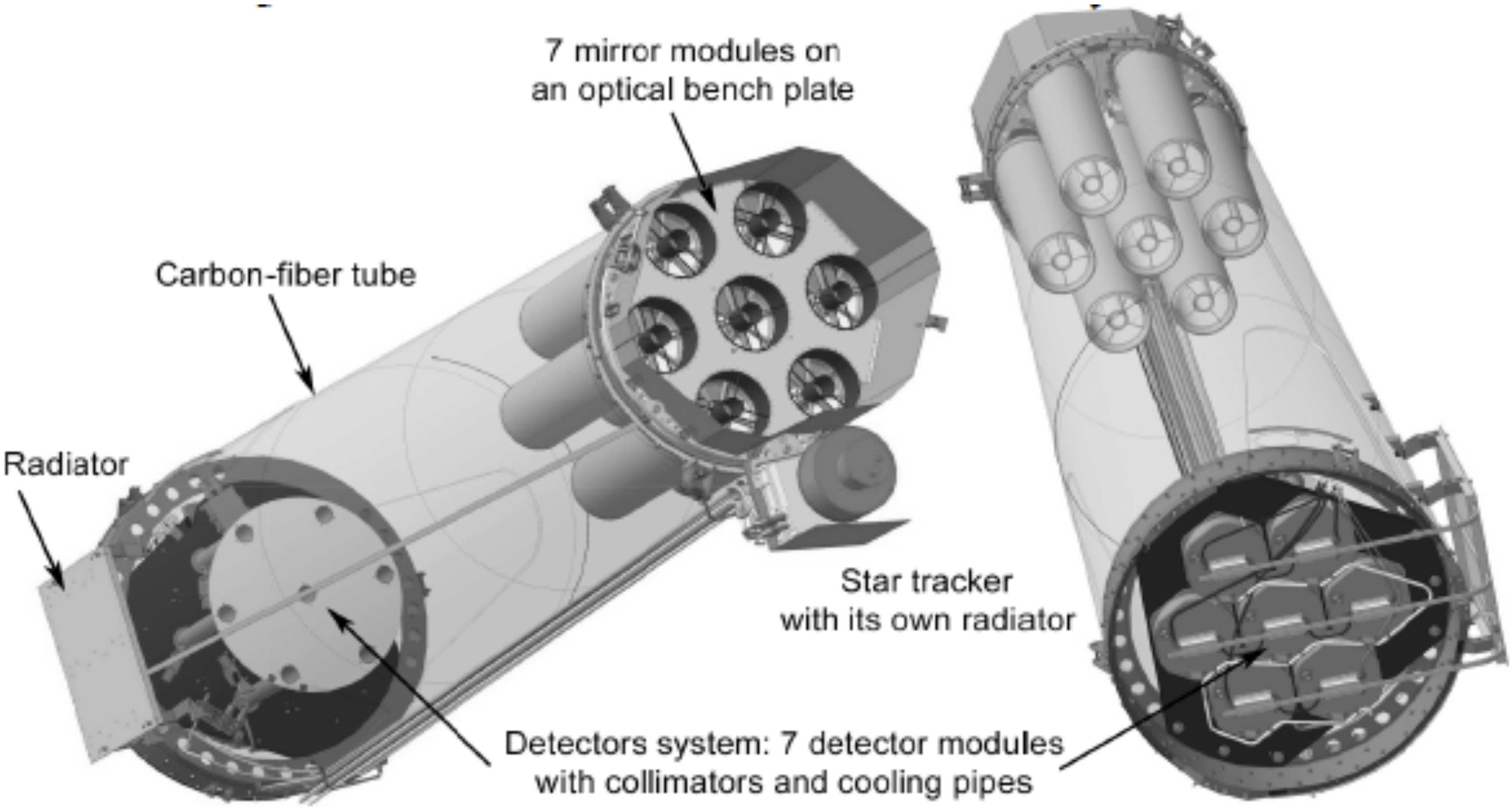
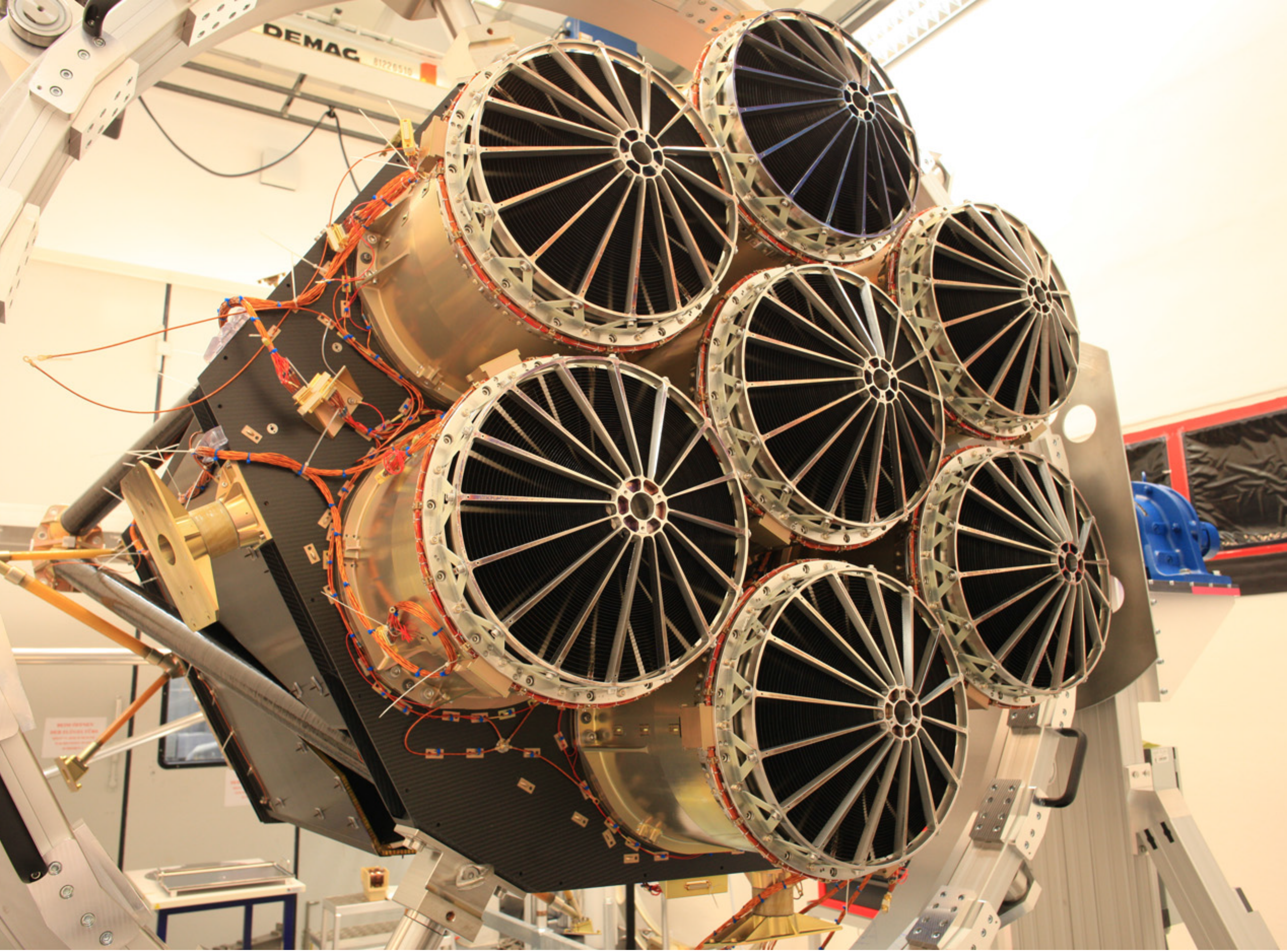
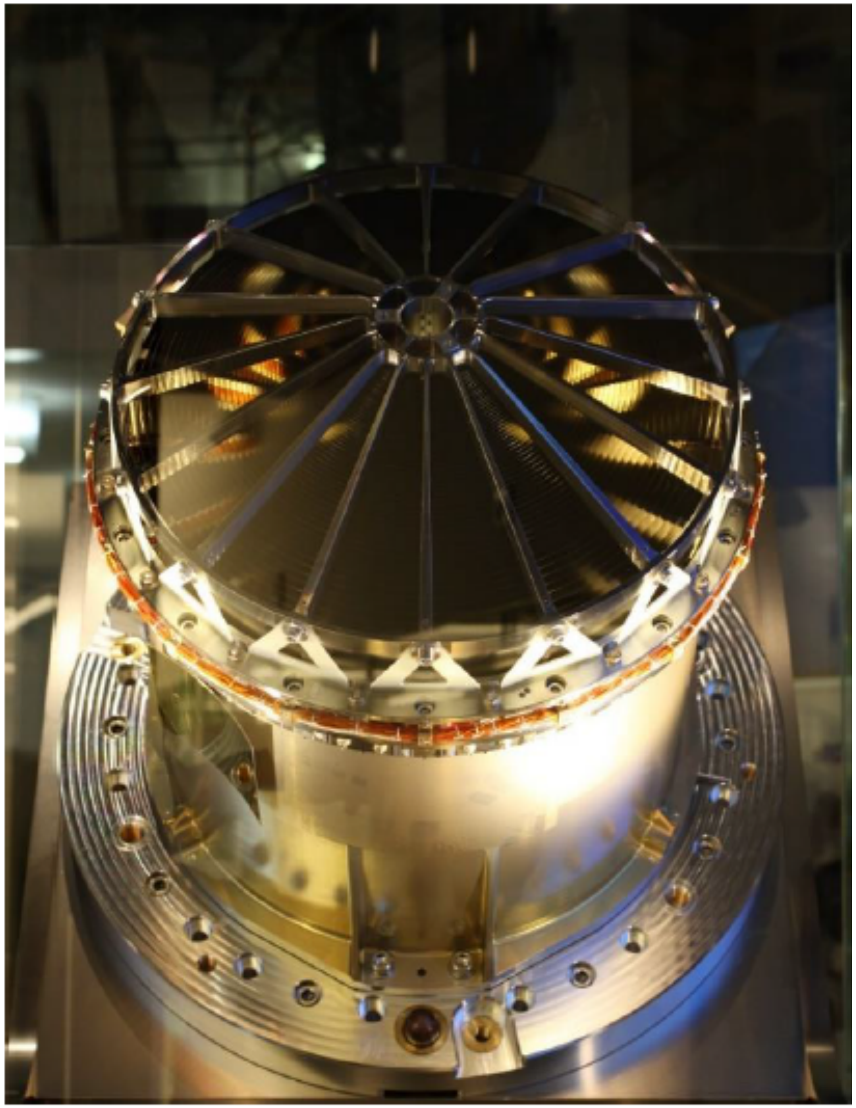
eROSITA



extended ROentgen Survey with an Imaging Telescope Array


DEMAG

eROSITA Mirror modules



Each module comprises: **54 paraboloid/hyperboloid mirror shells** (Wolter-I geometry)

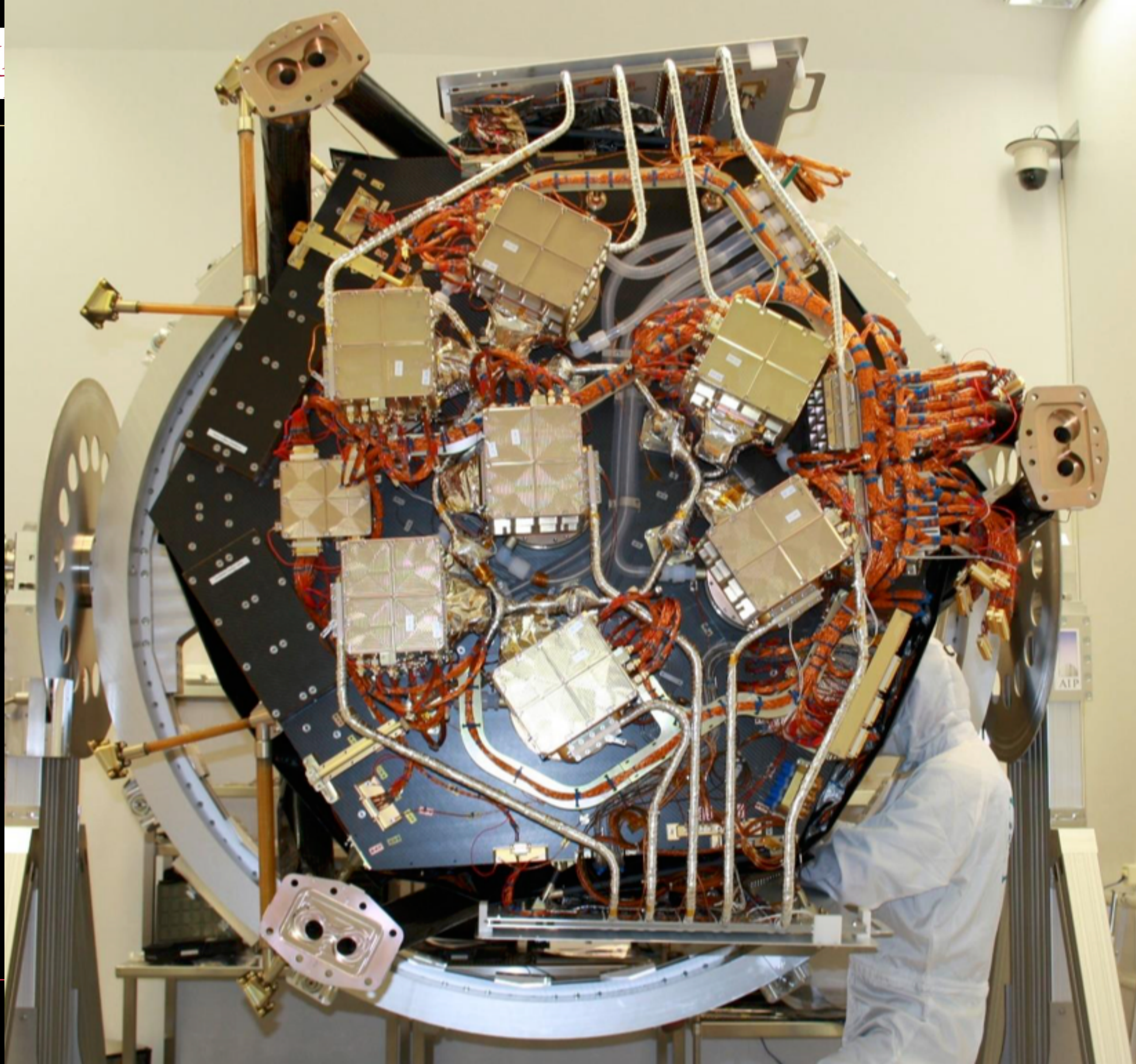
Outer diameter: **360 mm**

Focal length of: **1.600 mm**

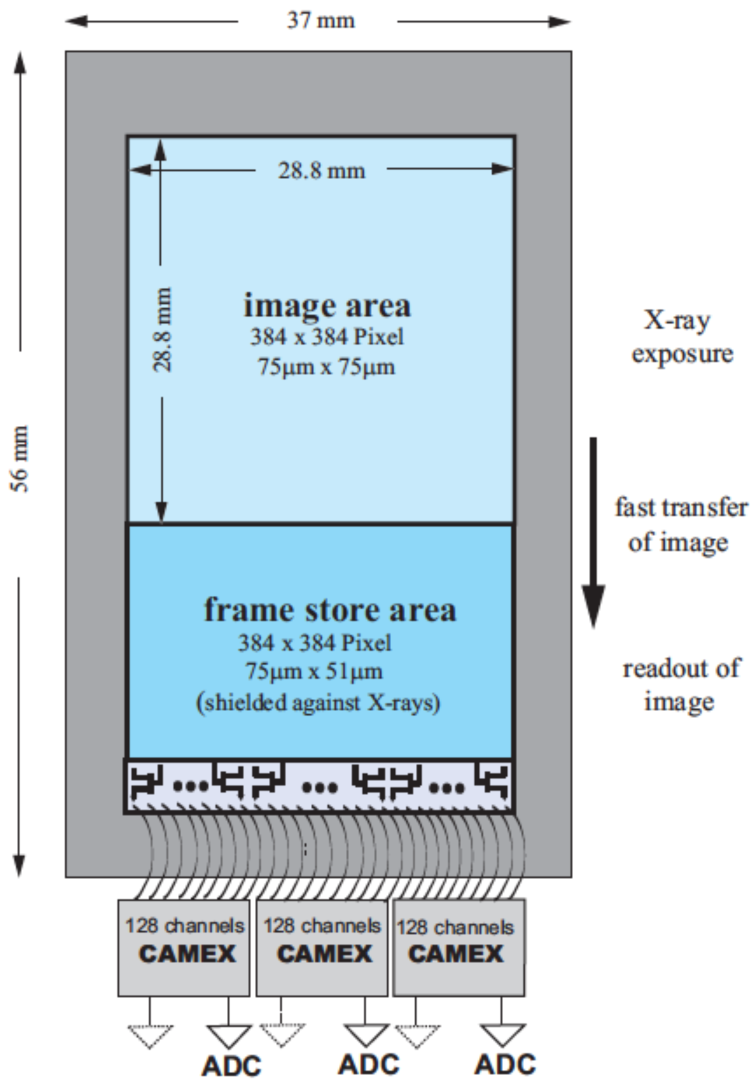
On-axis resolution of mirror modules: **16.3 arcsec HEW at 1.5 keV (av.)**

Baffle: **54 concentric invar cylinders mounted on spider wheels**

Magnetic electron deflectors behind the mirrors to reduce background due to low energy cosmic-ray electrons.


AIP

Frame store pnCCD

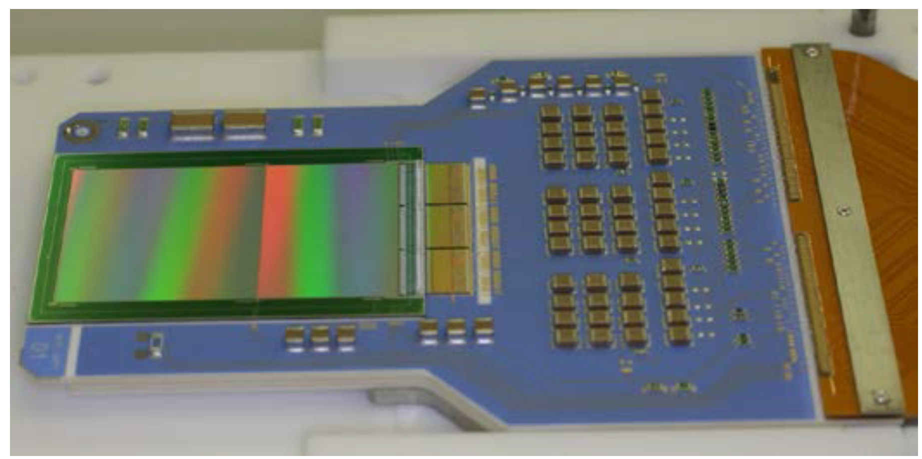


eROSITA-CCDs: **384 x 384 pixels**
Image area: **28.8 mm x 28.8 mm**

Field of view: **1.03° diameter**

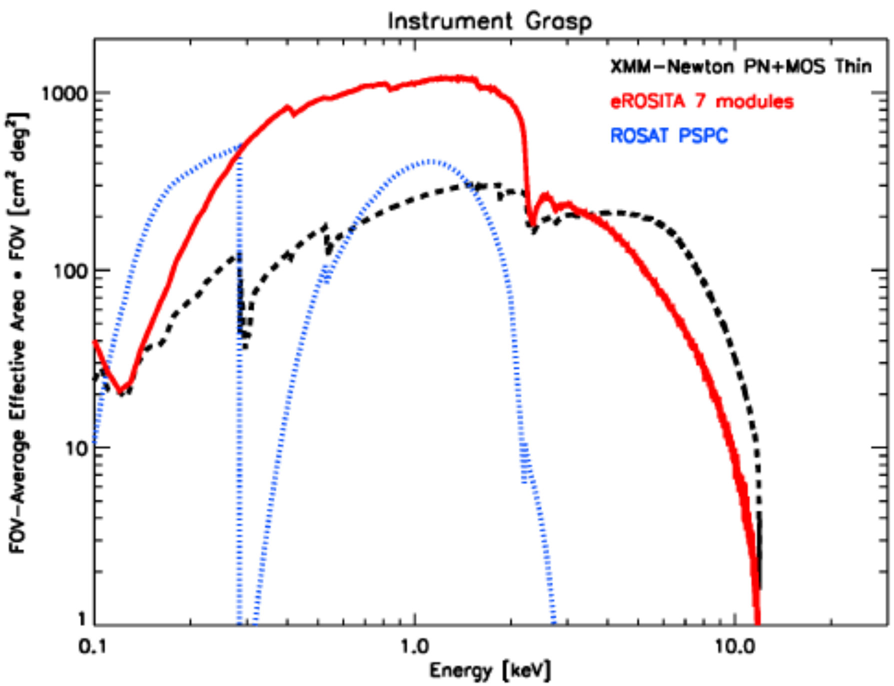
The 384 channels are read out in parallel using special **ASICs ("CAMEX")**

Nominal integration time: **50 ms**
Operation temperature: **-90 °C**



Science → imaging, survey, no timing.

Instrument Grasp → all sky survey

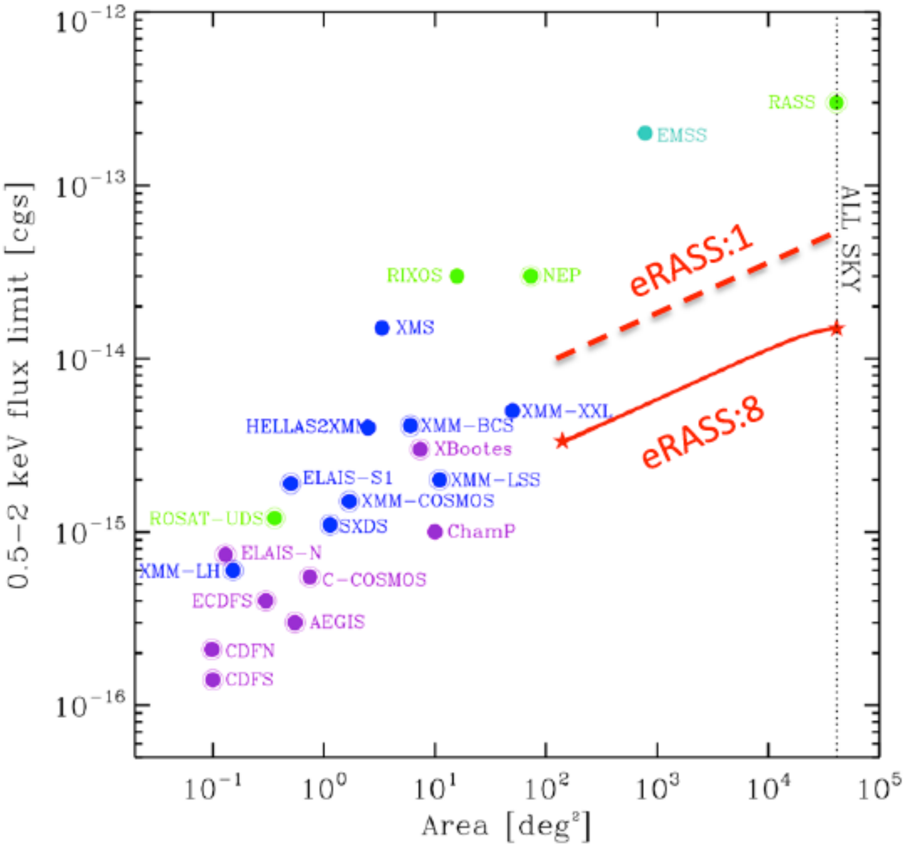


eROSITA will provide the first imaging all-sky survey in the 2–10 keV range

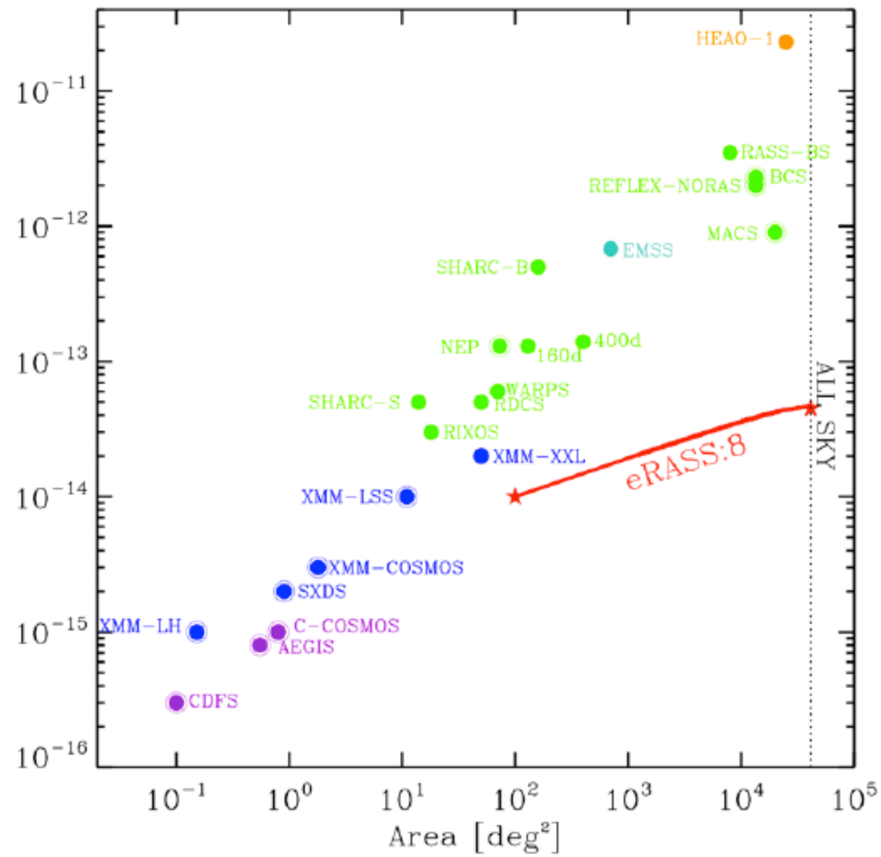
Primary reference for CTA source identification and multi wavelength correspondences

- Effective area at 1keV comparable with XMM-Newton
- **Factor ~7-8 larger surveying speed**
- 4 years dedicated to all sky survey (with estimated 70-80% efficiency)

Waiting for eROSITA



All sky: 10^{-14} (0.5-2 keV)
2×10^{-13} (2-10 keV) [erg/cm²/s]



All sky: 3.4×10^{-14} (0.5-2 keV)

Merloni et al. 2012

A powerful survey machine

- **110k Clusters** with > 50 counts (secure detection)
- **23k Clusters** with accurate red-shift determination (from X-rays alone)
- **2k Clusters** with accurate Temperature determination

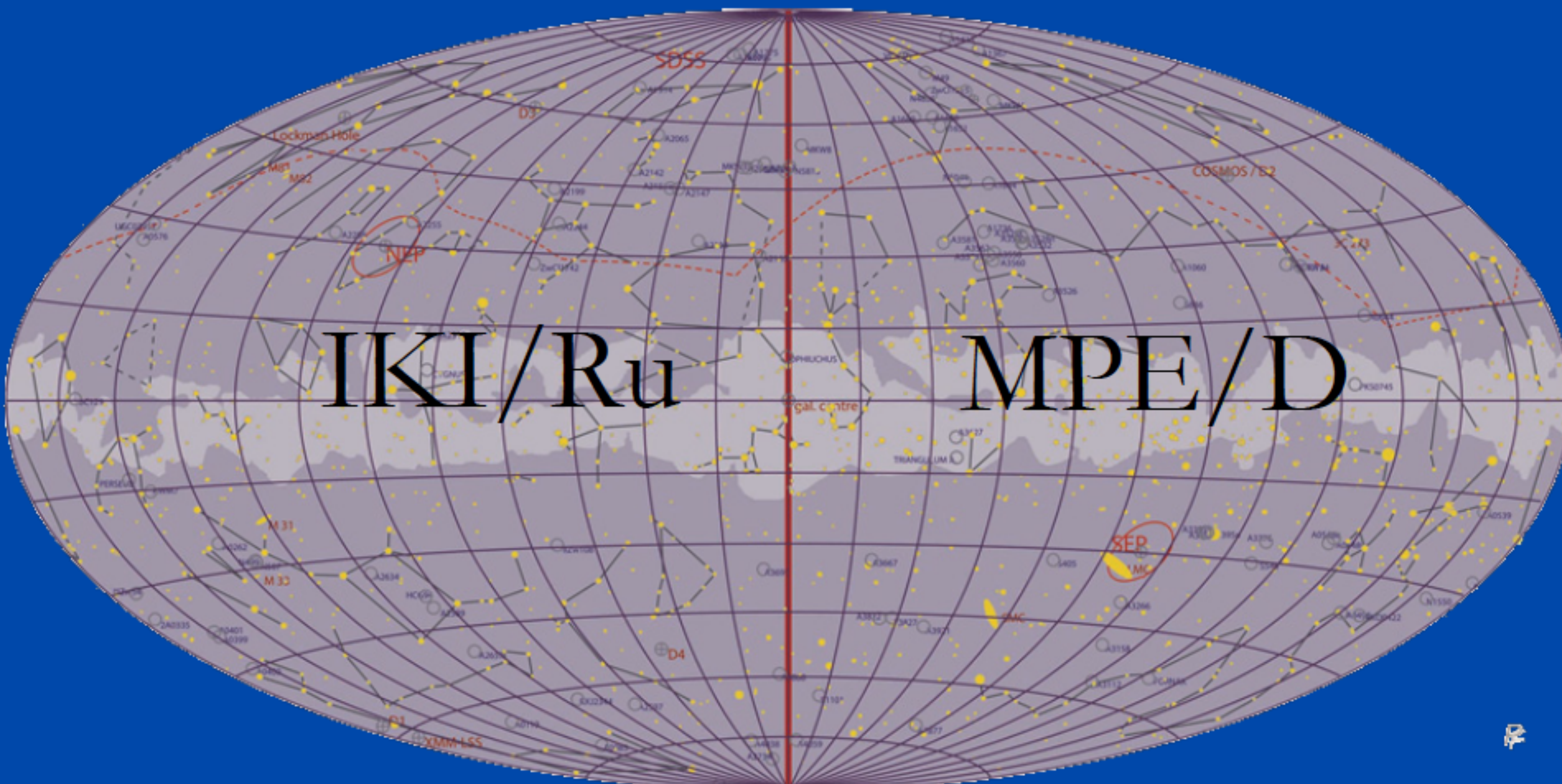
- **3M of AGNs** including the most luminous, the obscured ones, and High z AGNs

- **600k active stars** (young, magnetic)

- **Population studies of X-ray binaries in the MW and nearby galaxies**

Active follow-up campaigns!

eROSITA: Sky division ….

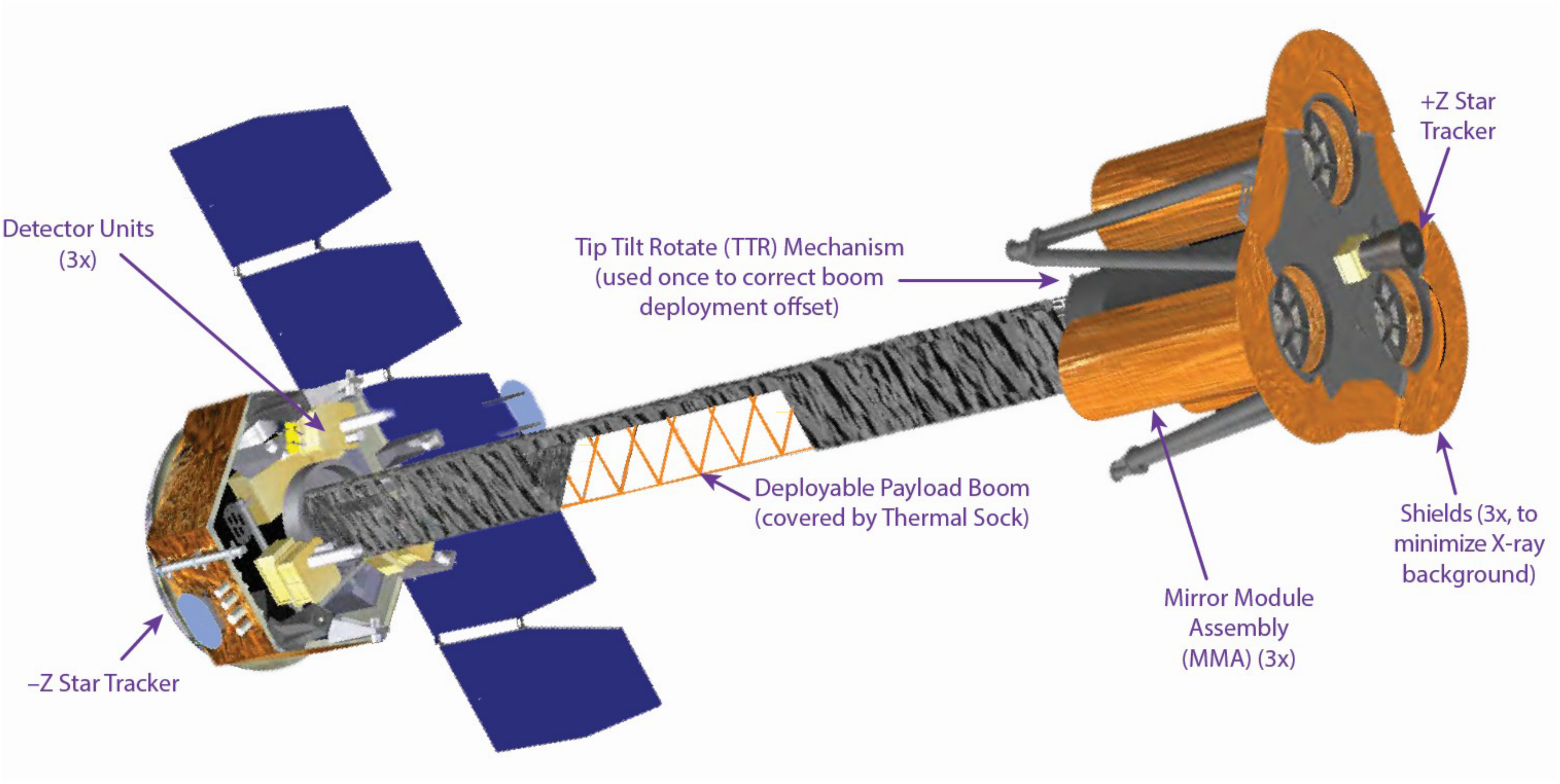


Part II.2

IXPE, XIPE: opening the X-ray polarimetry window

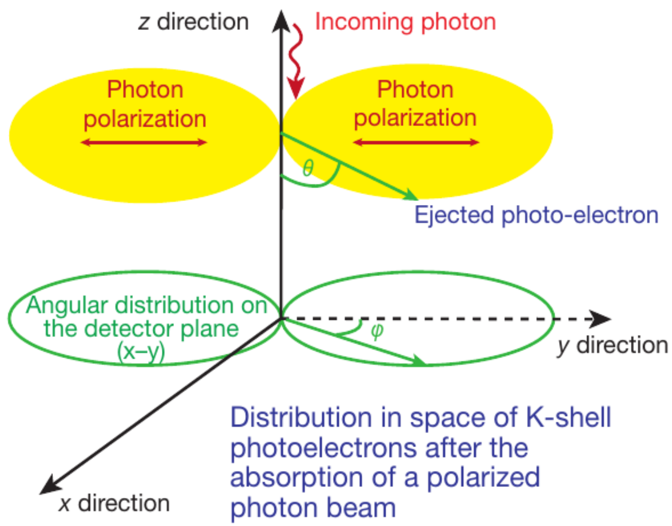
Imaging X-ray Polarimetry Explorer (IXPE, 2020)

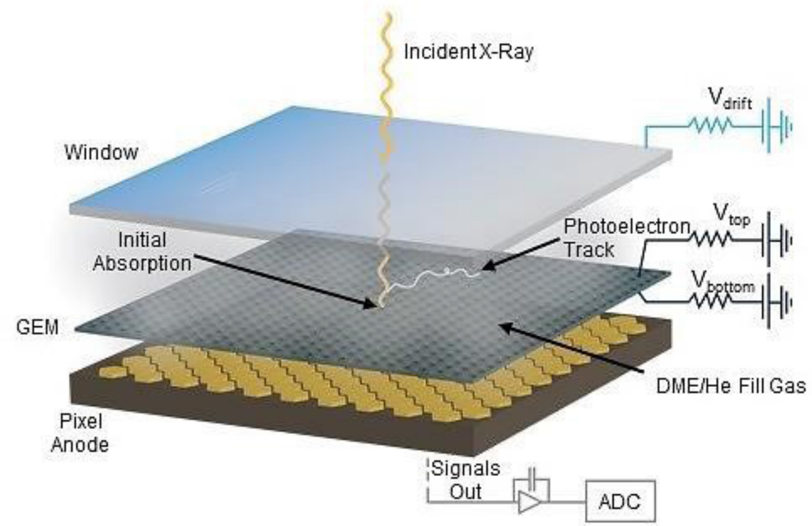
With IXPE, X-ray polarimetry will at last join timing, imaging and spectroscopy



The IXPE concept

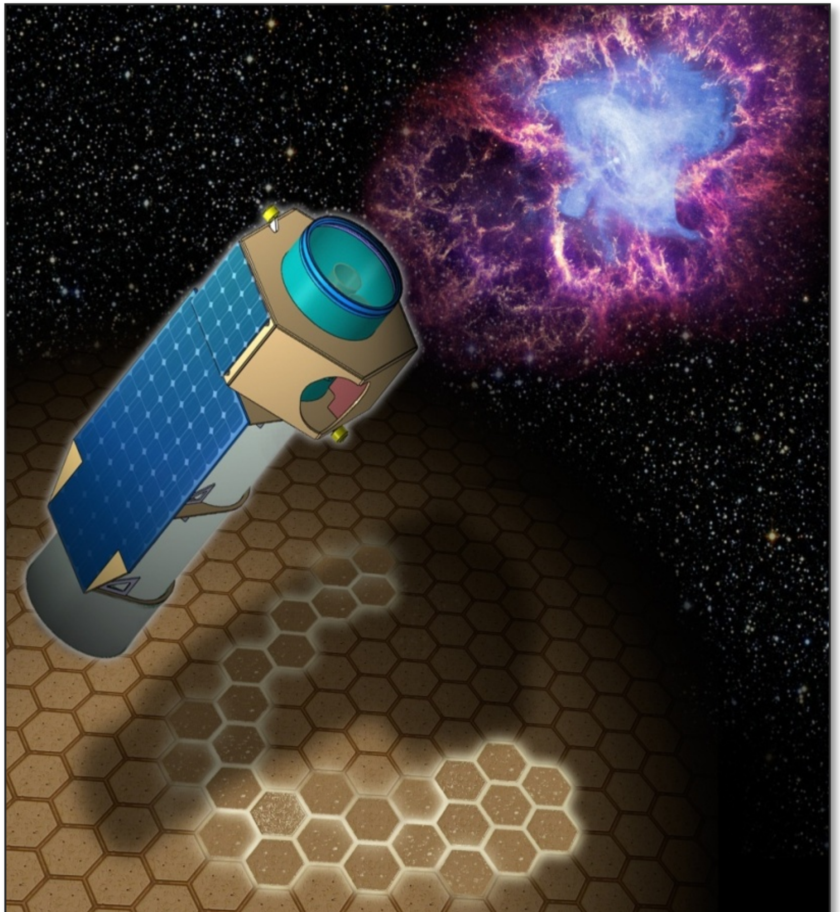
- Three redundant telescope-detector systems
- **Gas pixel electron tracking detectors** developed in Italy
- Replicated X-ray telescopes with < 30'' angular resolution (half-power diameter) developed at MSFC

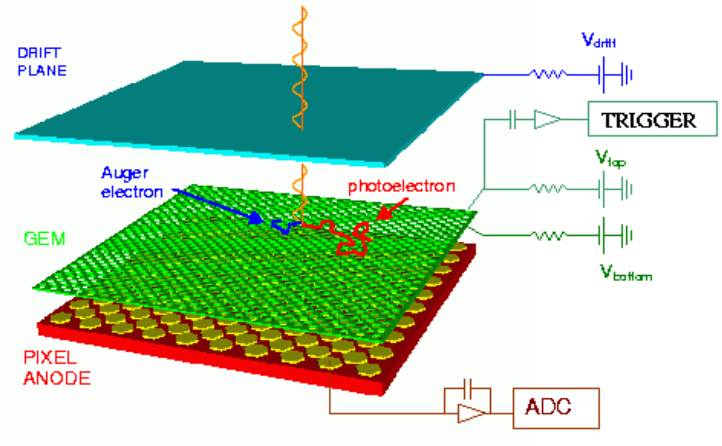




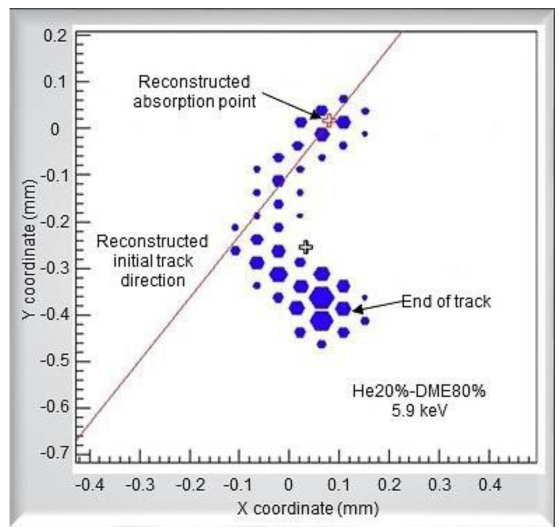
$$\frac{\partial\sigma}{\partial\Omega} = r_0^2 \frac{Z^5}{137^4}\left(\frac{mc^2}{h\nu}\right)^{7/2} \frac{4\sqrt{2}\sin^2(\theta)\cos^2(\varphi)}{(1-\beta\cos(\theta))^4}$$

XIPE: an M4 study by ESA





Gas Pixel detectors



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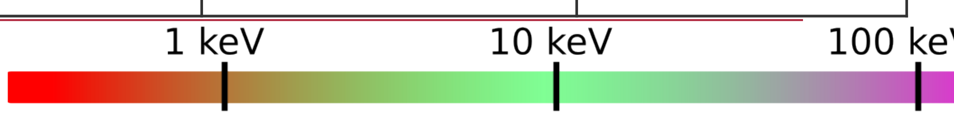
The science program of XIPE

Scientific goal	Sources	< 1keV	1-10	> 10 keV
Acceleration phenomena	PWN	yes (but absorption)	yes	yes
	SNR	no	yes	yes
	Jet (Microquasars)	yes (but absorption)	yes	yes
	Jet (Blazars)	yes	yes	yes
Emission in strong magnetic fields	WD	yes (but absorption)	yes	difficult
	AMS	no	yes	yes
	X-ray pulsator	difficult	yes (no cyclotron ?)	yes
	Magnetar	yes (better)	yes	no
Scattering in aspherical geometries	Corona in XRB & AGNs	difficult	yes	yes (difficult)
	X-ray reflection nebulae	no	yes (long exposure)	yes
Fundamental Physics	QED (magnetar)	yes (better)	yes	no
	GR (BH)	no	yes	no
	QG (Blazars)	difficult	yes	yes
	Axions (Blazars, Clusters)	yes ?	yes	difficult

Probing the injection site!



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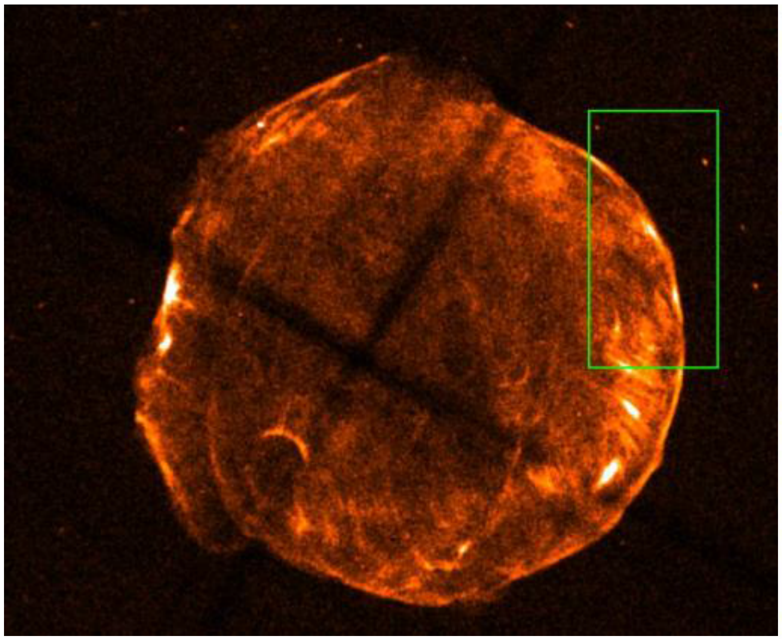
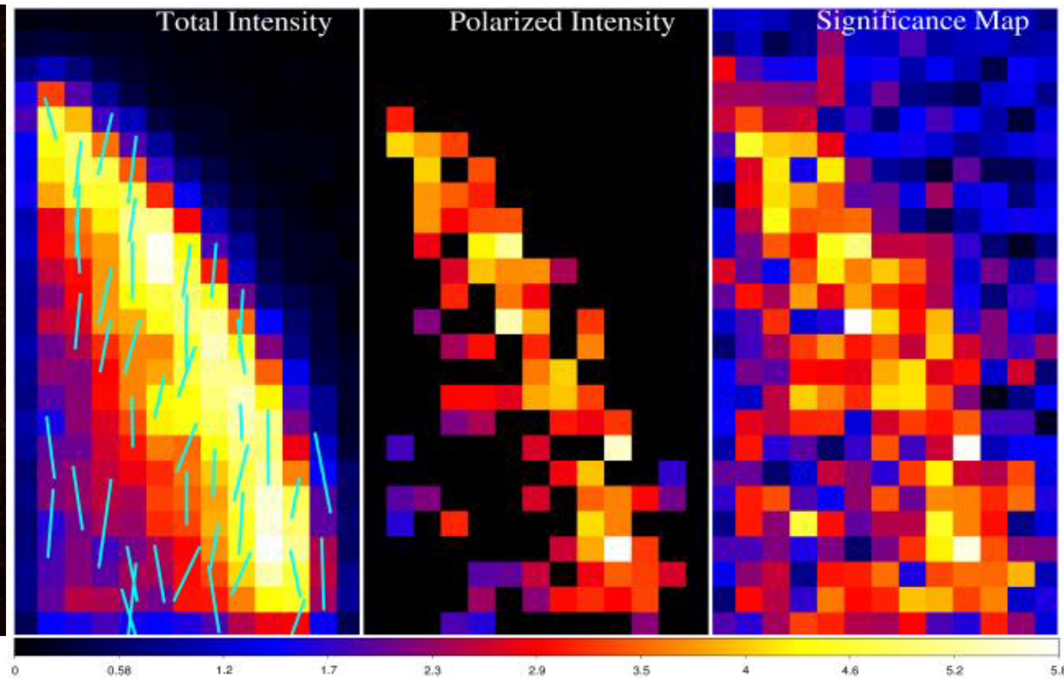
Polarized X-rays and SNRs

Image in spatial detail the turbulence level of magnetic fields → constrain DSA

Intensity *Pol. Intensity* *Significance*





Ms Simulation of a portion of Tycho's SNR, using a theoretically calculated polarisation map as input for XIPE**: total intensity, polarised intensity (polarised fraction times intensity and significance map**

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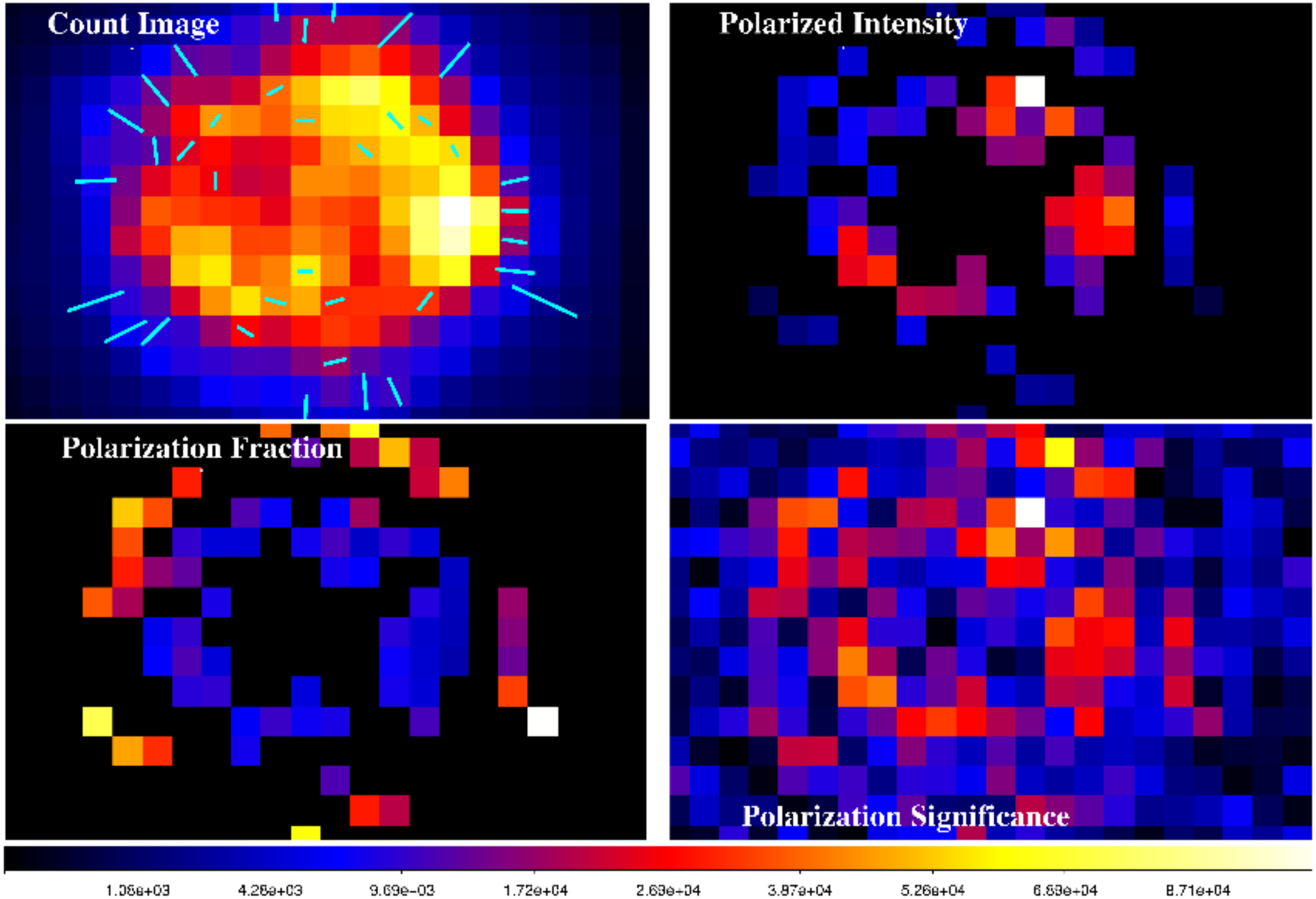
XIPE view of CAS A

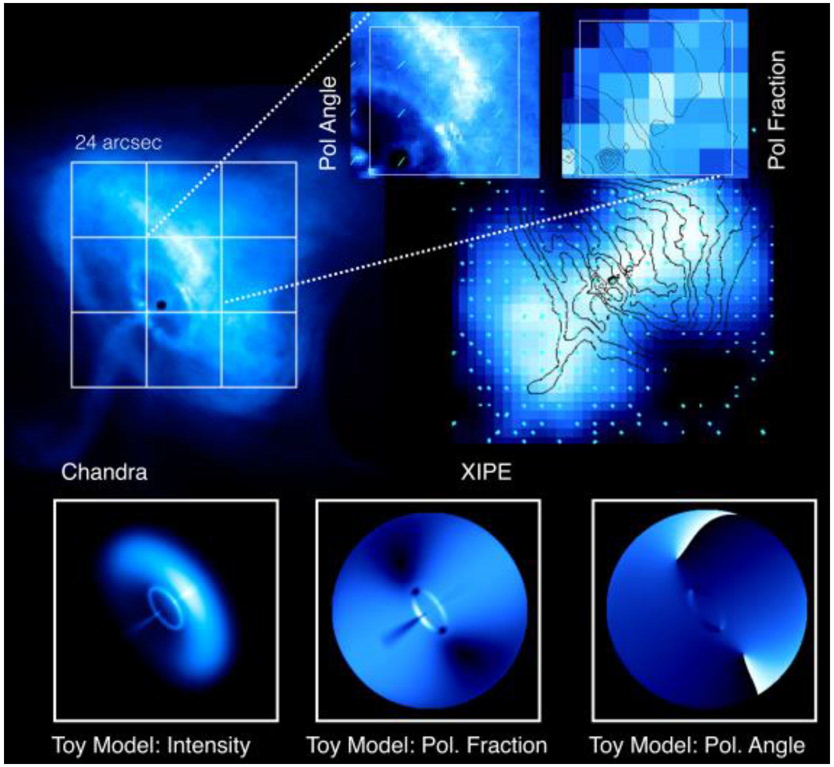


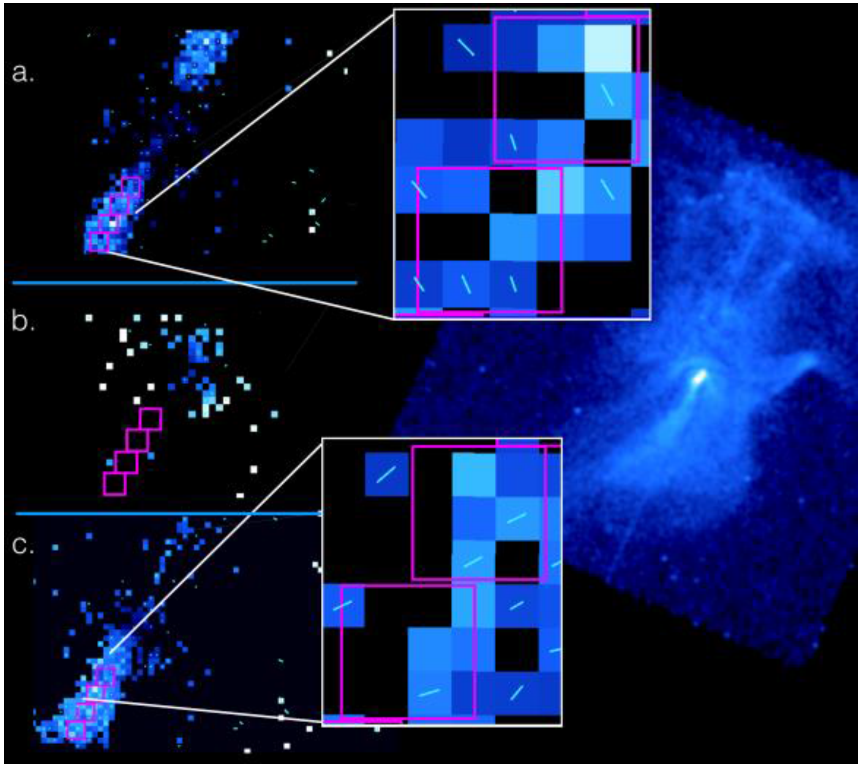
What is required is effective area and angular resolution.

Beyond IXPE… and XIPE seems to be not top of the list for M4 selection

Crab and PWNae

The XIPE view of the Crab:





Spatially-resolved observations with *XIPE*, at its angular resolution of ≤30”, will determine the magnetic field orientation and the level of turbulence in the torus, the jet, and at various distances from the pulsar…

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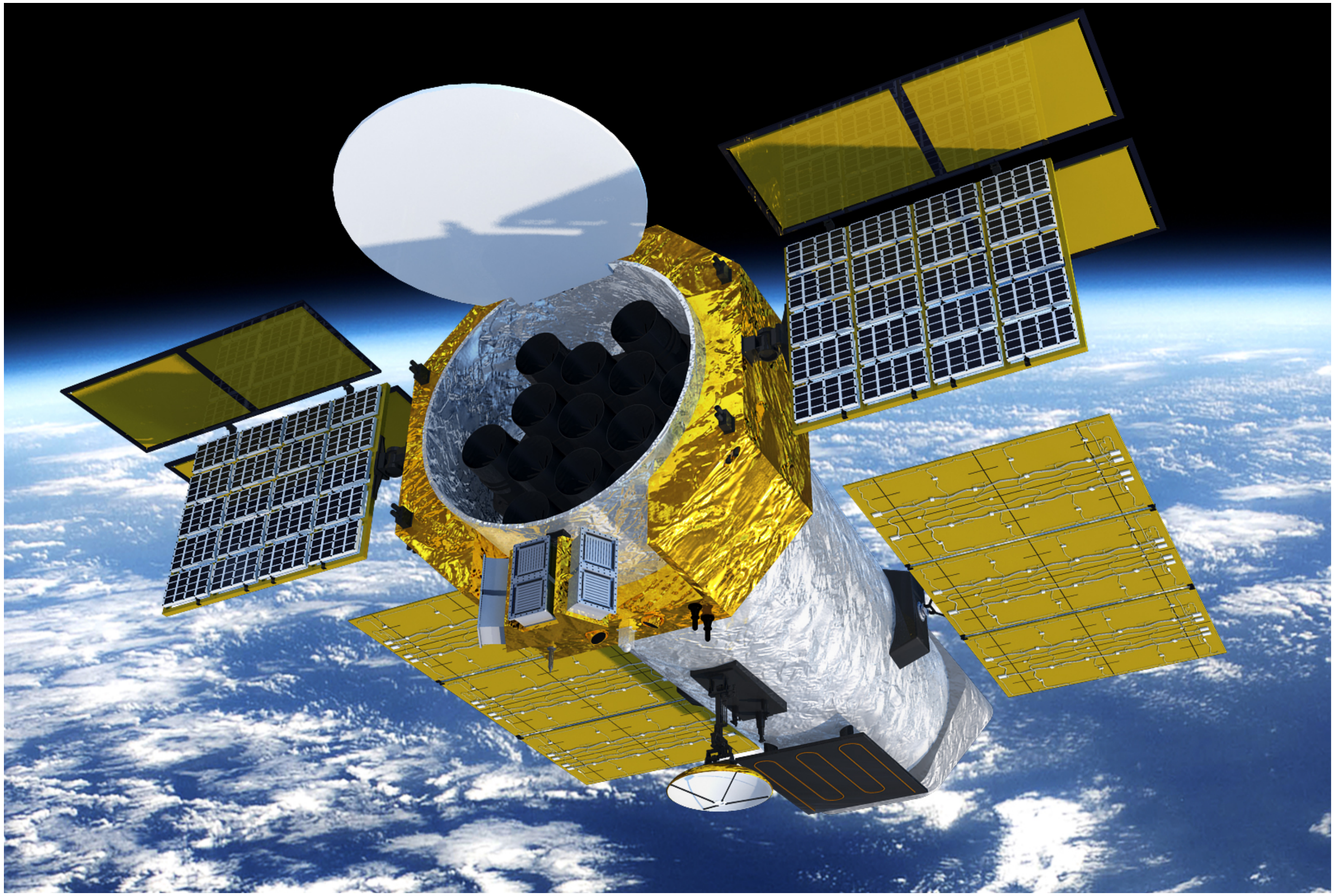
Part II.2

eXTP

eXTP

enhanced X-ray Timing and Polarimetry mission



A Large mission, led by China, with Europe participating, launch 2025

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Key science goals

eXTP is a machine to study the **extreme of physics**: understanding the behavior of matter under **extreme conditions of density, gravity and magnetism**

Dense Matter: which is the state of matter at supranuclear densities (i.e., in the neutron star's interior)? Exotic states of matter? Quark stars?

Strong Gravity: what are the properties of space-time under extreme gravity (i.e., in the vicinity of neutron stars and black holes)? Any deviations from Einstein's General Relativity theory?

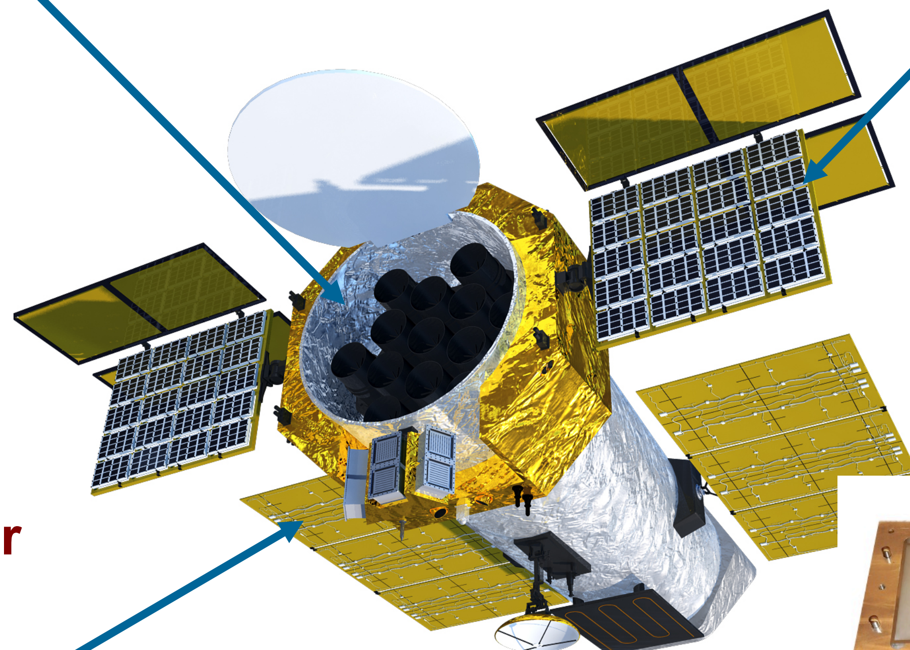
Strong Magnetism: which is the behavior of light in the presence of ultra-strong magnetic fields (e.g., in magnetars)? Are the predictions of the QED theory verified?

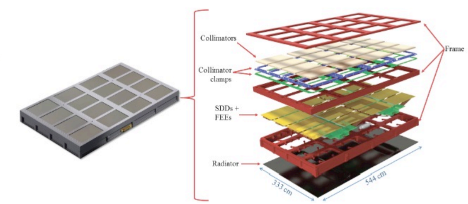
The astrophysics of bright sources!

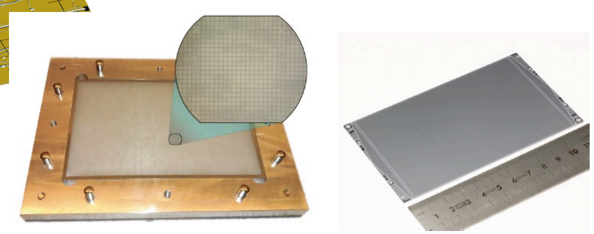
eXTP current configuration

9 Tel. Spectroscopy Focusing Array
4 Tel. Polarimetry Focusing Array

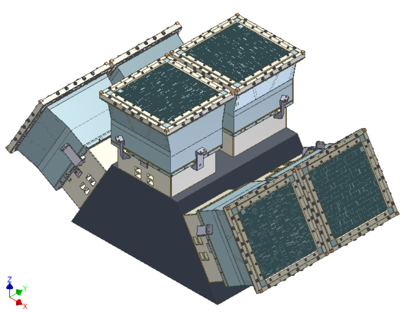
Large Area Detector







Wide Field Monitor



4.5 ton, lifetime 8 years, launched with LM-7, Orbit 550km, 0 deg

Payload

LAD

40 arrays SDD

Energy band：2-50 keV

Collimated FOV 1deg FWHM

Time resolution: 1us

Energy res.: 200eV@ 6keV

Sensitivity：0.01 uCrab（10^4s）

Effective area：3.4m^2@6keV

Soft Focusing Array

9 telescopes: focal length 5.25m, Diameter 450 mm, SDD

Energy band: 0.5-10 keV

FOV：12 arcmin

Time resolution：10 us

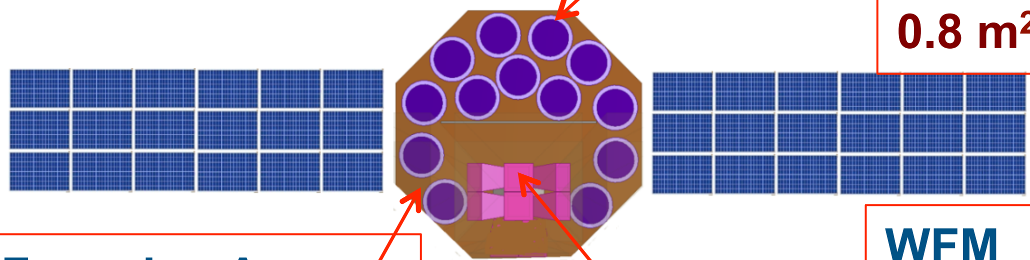
Energy res.: 180eV@6keV

Ang. Res.: 1 arcmin (HPD)

Sensitivity：0.16uCrab（10^4s）

Effective area: 5000cm^2@6keV

0.8 m^2 between 1-2 keV



Polarimetry Focusing Array

4 arrays focal length 5.25 m, diameter 450 mm

Energy band: 2-10 keV

FOV:12 arcmin

Time resolution: 500us

Energy res: 1.8keV@6keV

Angular resolution：15 arcsec

Sensitivity：5 uCrab（10^4s）

Effective area：900cm^2@2keV

WFM

3 arrays，SDD

Energy band：2-50 keV

FOV：1.33PI

Time resolution：2 us

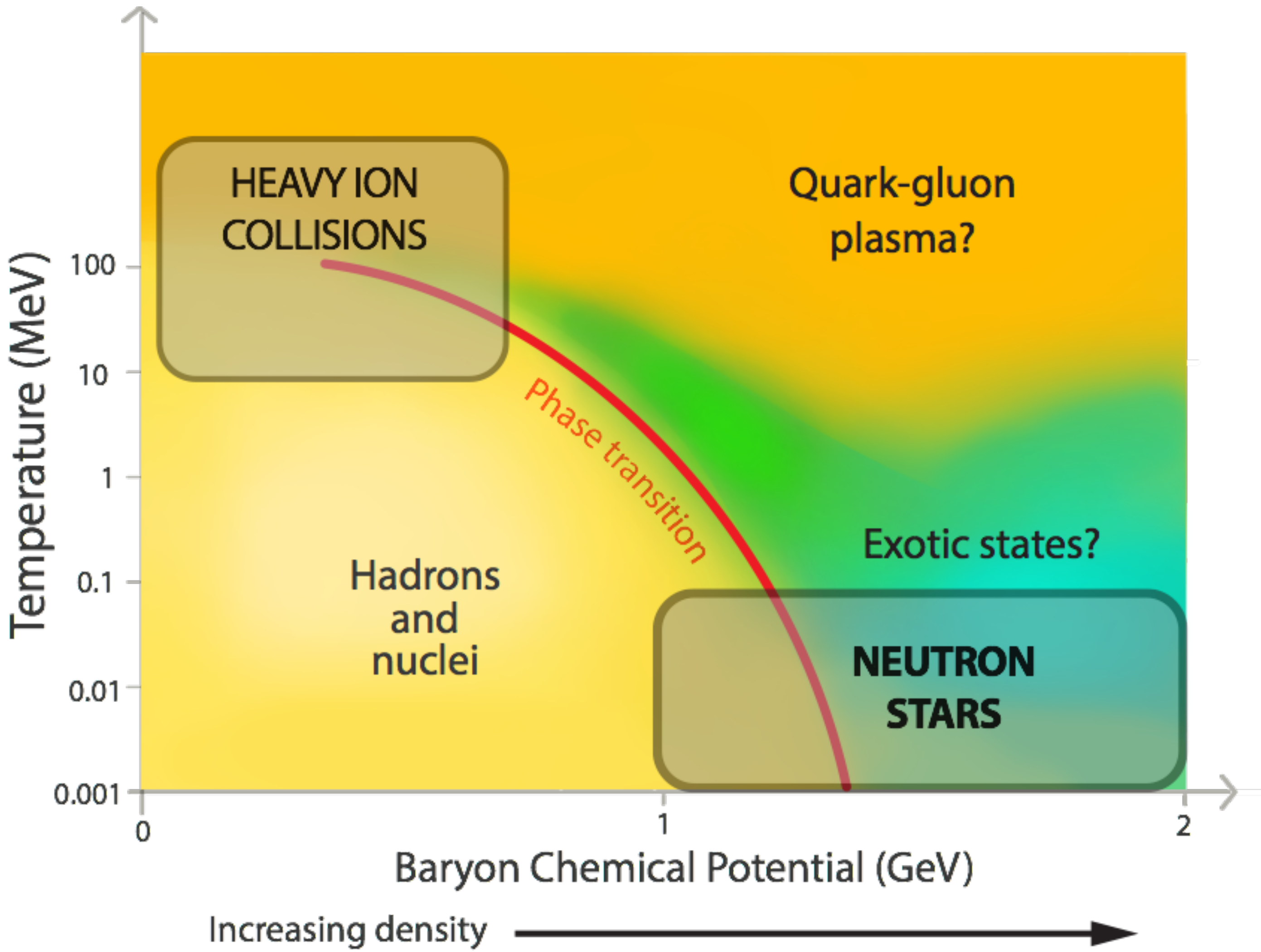
Energy resolution：300eV@6keV

Angular resolution：4.5 arcmin

Sensitivity：3uCrab（2x104s）

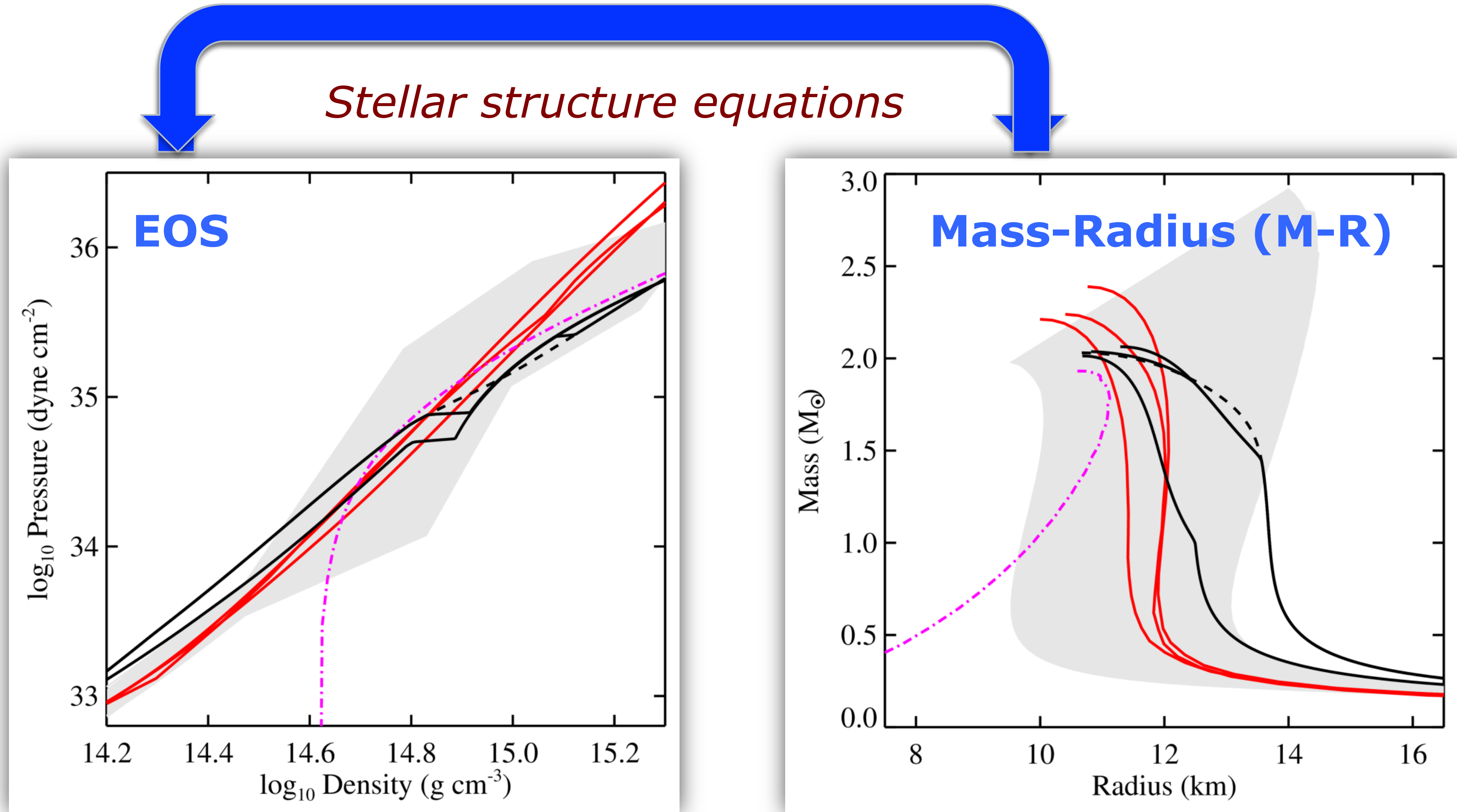
Effective area：170cm^2@6keV

Strong Force Physics



***Neutron stars: the densest** and most **neutron-rich** matter **in the Universe**.*

Strong force, EOS, and mass-radius relation



WE MUST MEASURE **BOTH M AND R** TO **HIGH PRECISION**
(LOW STATISTICAL AND SYSTEMATIC ERRORS) FOR A **RANGE OF M**.

*Anna L. Watts et al. Rev. Mod. Phys. **88**, 021001 (2016)*

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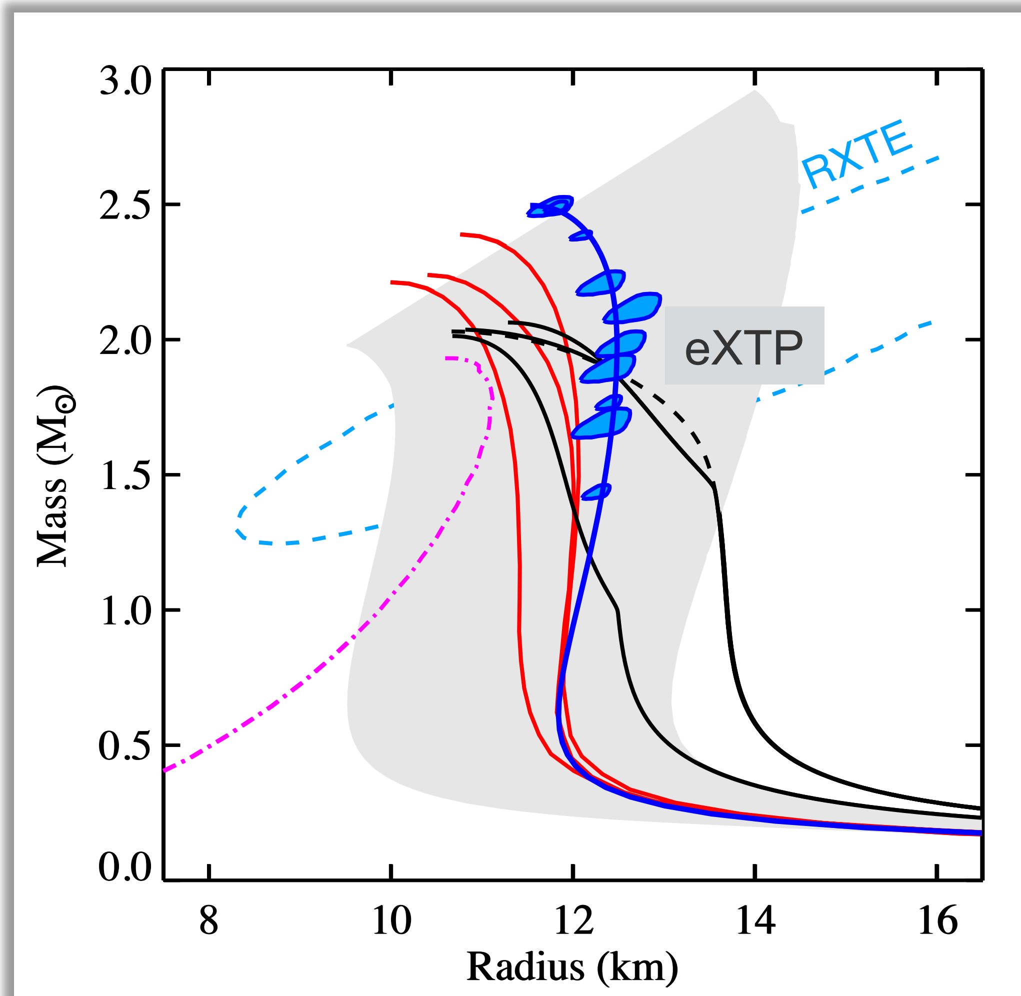
Pulse profile modeling of AMSPs



Detailed simulations carried out to evaluate fitting procedure and accuracies *(Lo et al. 2013, ApJ)*

Few % accuracy needs ~10^6 photons: large area crucial →a few – several 100 ks

Multiple same-source cross-checks.

USING ONLY KNOWN SOURCES, PULSE PROFILE MODELLING MEASUREMENTS WILL MAP THE M-R RELATION AND HENCE THE EOS.

M-R to EOS inversion makes no model assumptions except continuity

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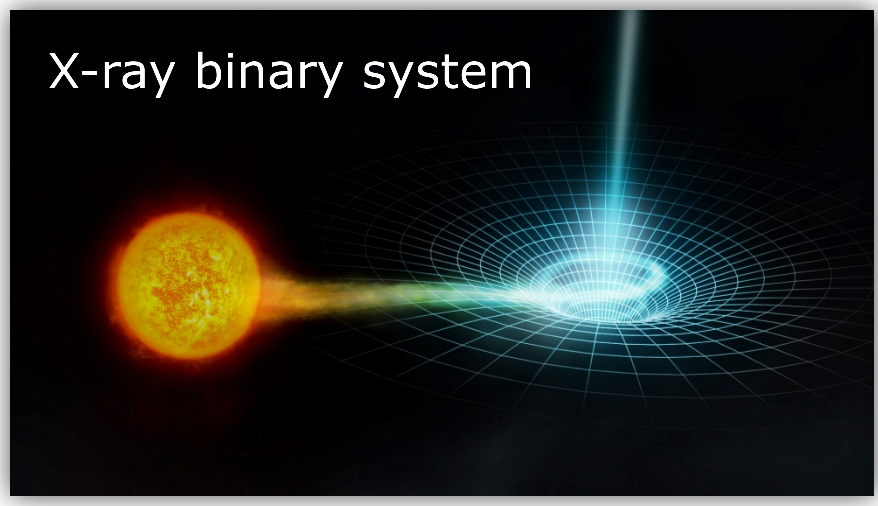
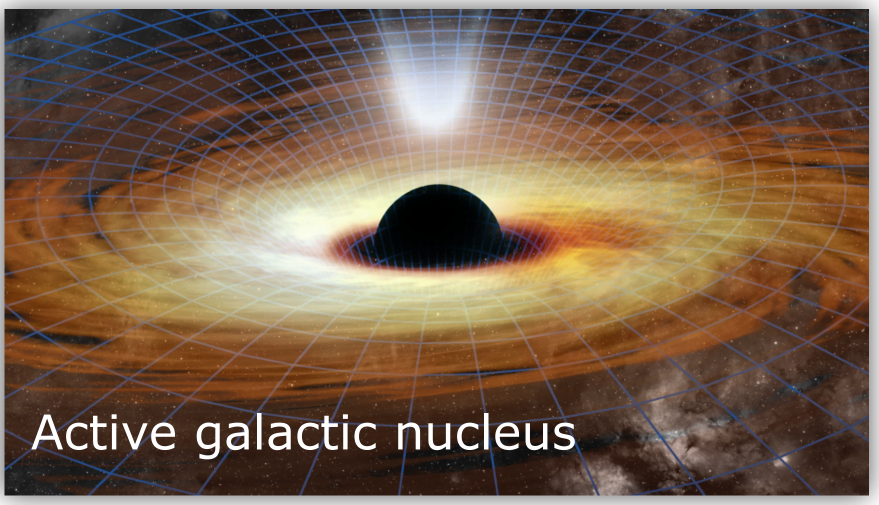
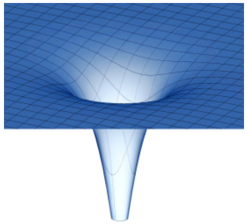
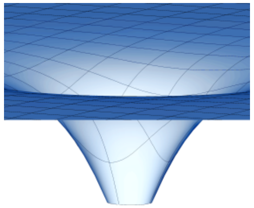




eXTP covers wide mass range in uniform setting



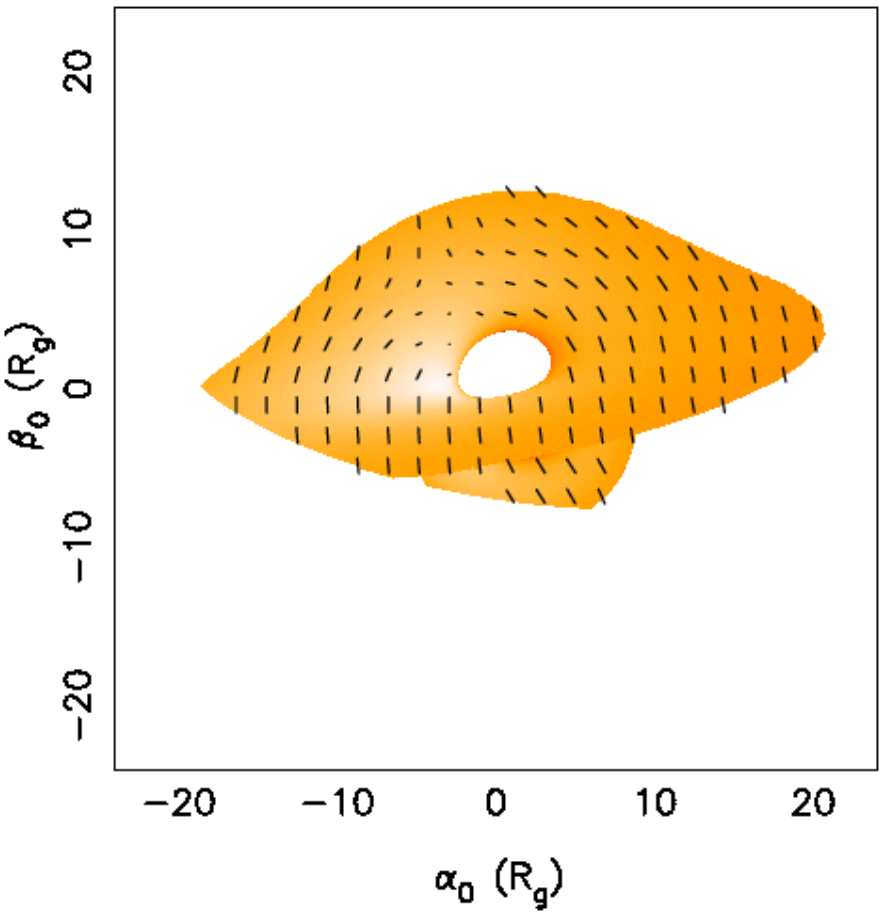
Stellar mass black hole
(or neutron star)
Strongly curved spacetime.
(10^{16} times Solar)

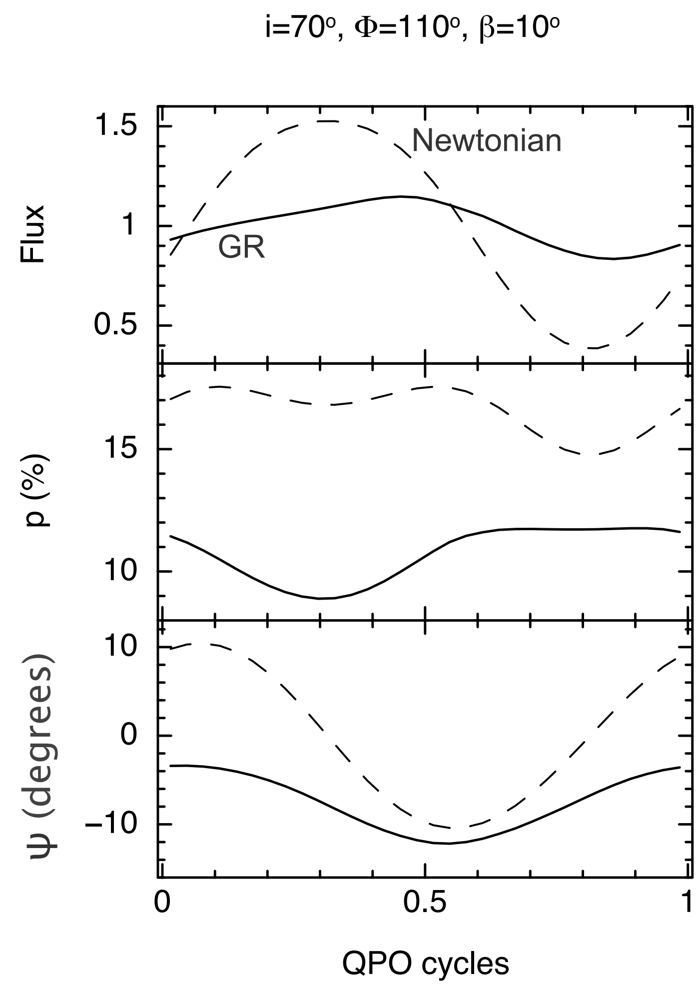


Supermassive black hole
Weakly curved spacetime
(~Solar)

TESTS OF GR PREDICTIONS IN THE STRONG FIELD REGIME OF GRAVITY. COMPLEMENTARY TO GRAVITATIONAL WAVE EXPERIMENTS: eXTP PROBES STATIONARY SPACETIME

Polarization variability in LFQPOs





www.youtube.com/watch?v=ieZYYfCapJg&feature=youtu.be

Ingram et al (2015)

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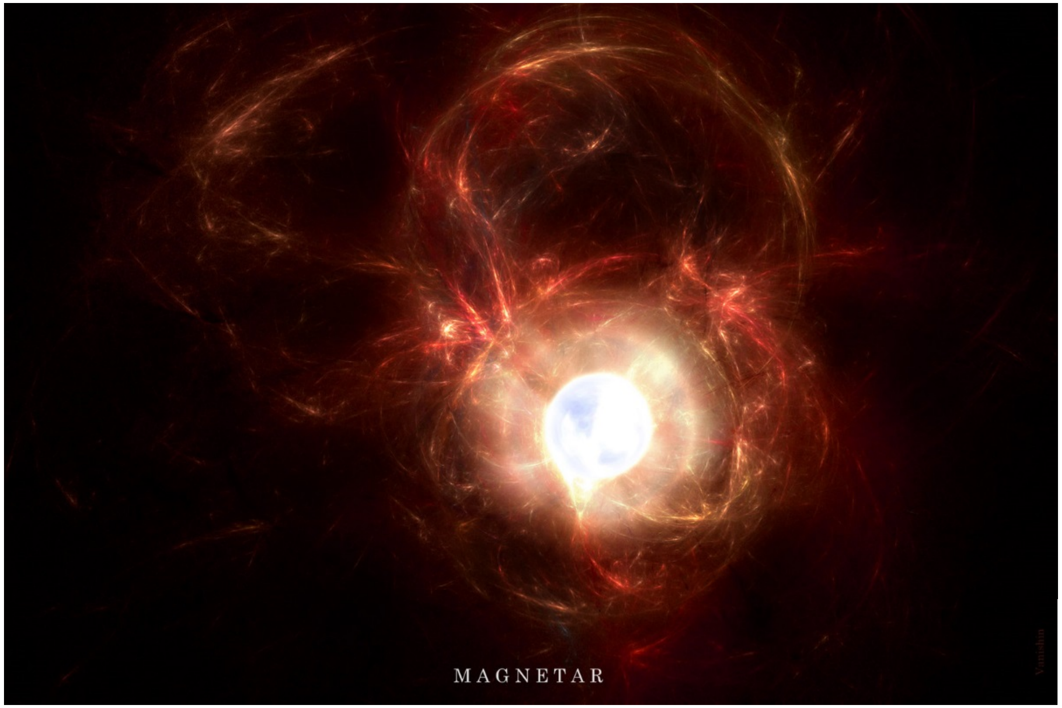
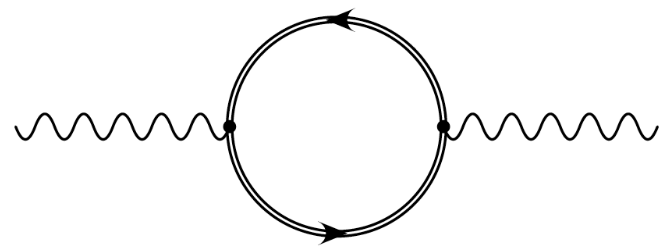
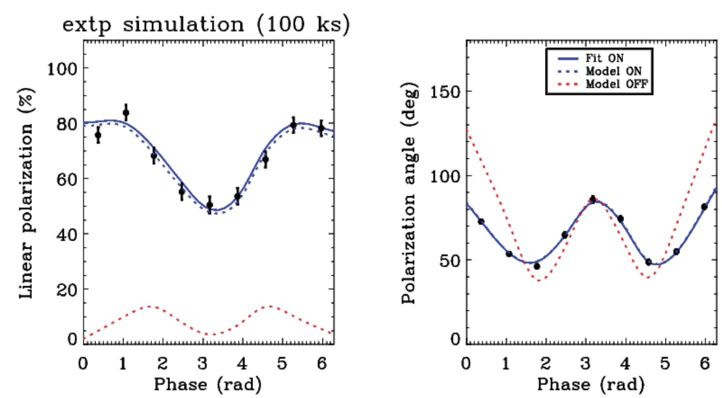


Accreting Pulsars and *Magnetars hosts neutron stars with magnetic fields of $10^{12\text{-}15}$ Gauss*



$$\Delta n = 4 \times 10^{-24} \mathrm{T}^{-2} B^2$$

Test QED effects → vacuum birefringence: *is the propagation of light in vacuum modified by the magnetic field?*



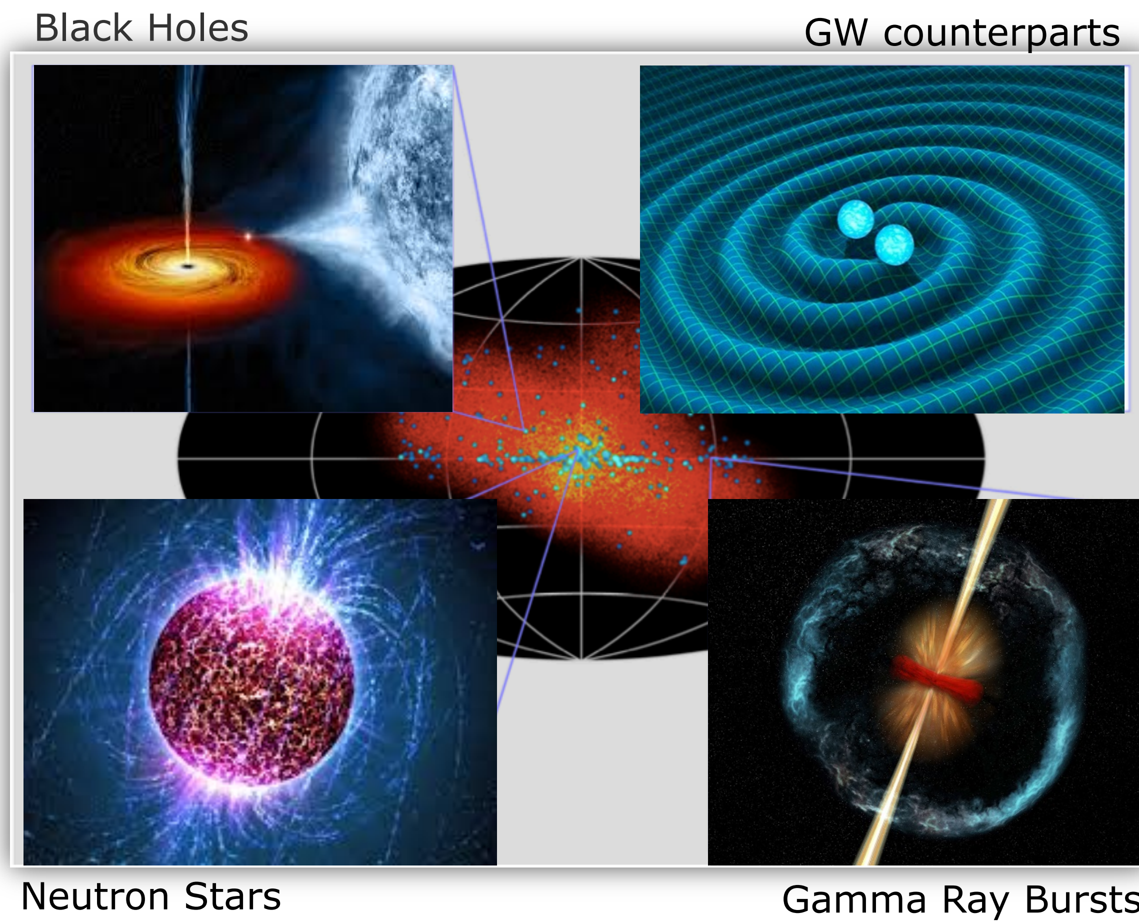
A powerful observatory machine

High-throughput X-ray spectroscopy and Polarimetry

All-Sky Monitoring

High-sensitivity and flexible X-ray observatory:

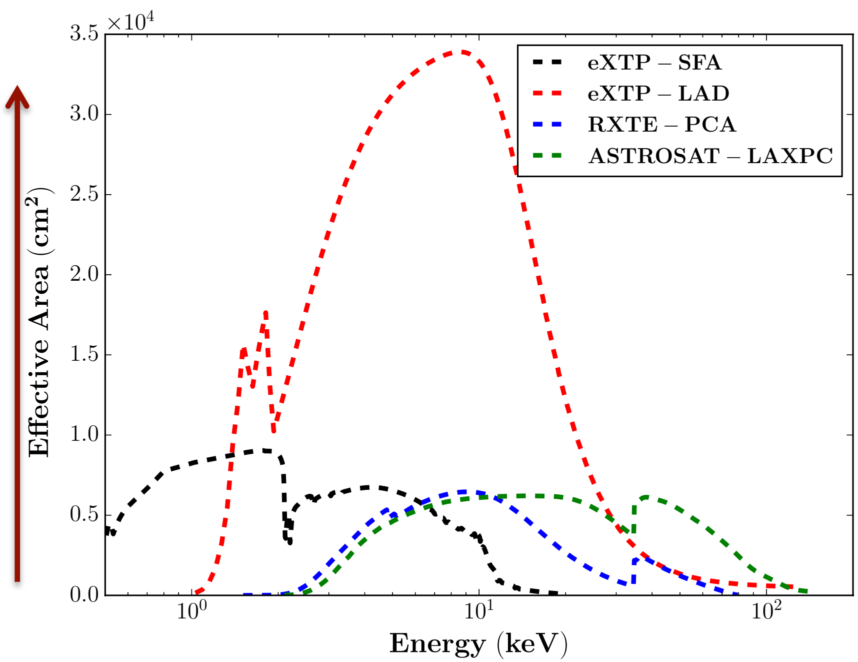
- Large impact for the wide scientific X-ray community
- Discovery and study of Gravitational Wave sources Counterparts
- Current eXTP Consortium: approx. 400 members



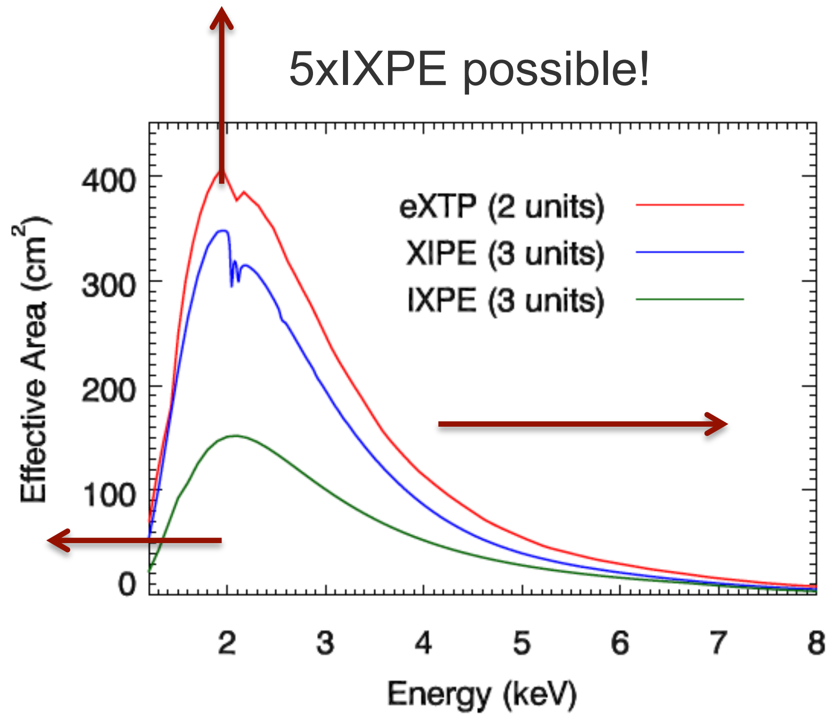
	Payload	Parameter	Specification
Soft Response	SFA	Energy range	0.5-10 keV
		Effective area	>7000 cm² @1 keV, >5000 cm² @6 keV
		Energy resolution	<180 eV FWHM @6 keV
		FoV/HPSD	12 arcmin / 1 arcmin
		Focal plane detector	Pixelated SDD (19 pixels)
Large area Hard Response	LAD	Energy range	2-30 keV (extended: 30-80 keV for out-FoV)
		Effective area	34000 cm²
		Energy resolution	<240 eV FWHM @6 keV
		FoV	1° (FWHM)
		Detector	Large area SDD (640 units, 40 Modules)
Polarization	PFA	Energy range	2-10 keV
		Effective area	>900 cm² @2 keV (including QE)
		Energy resolution	1.2 keV FWHM @6 keV
		FoV/HPD	12 arcmin / 20 arcsec
		Focal plane detector	GPD (4 units)
Monitoring	WFM	Energy range	2-50 keV
		Energy resolution	300 eV FWHM @6keV
		FoV	>4 sr (at 20% of peak response)
		Angular resolution	<5 arcmin
		Localization accuracy	<1 arcmin
		Detector	Large area SDD

Enlarging the discovery space

Unprecedented eff. area



5xIXPE possible!



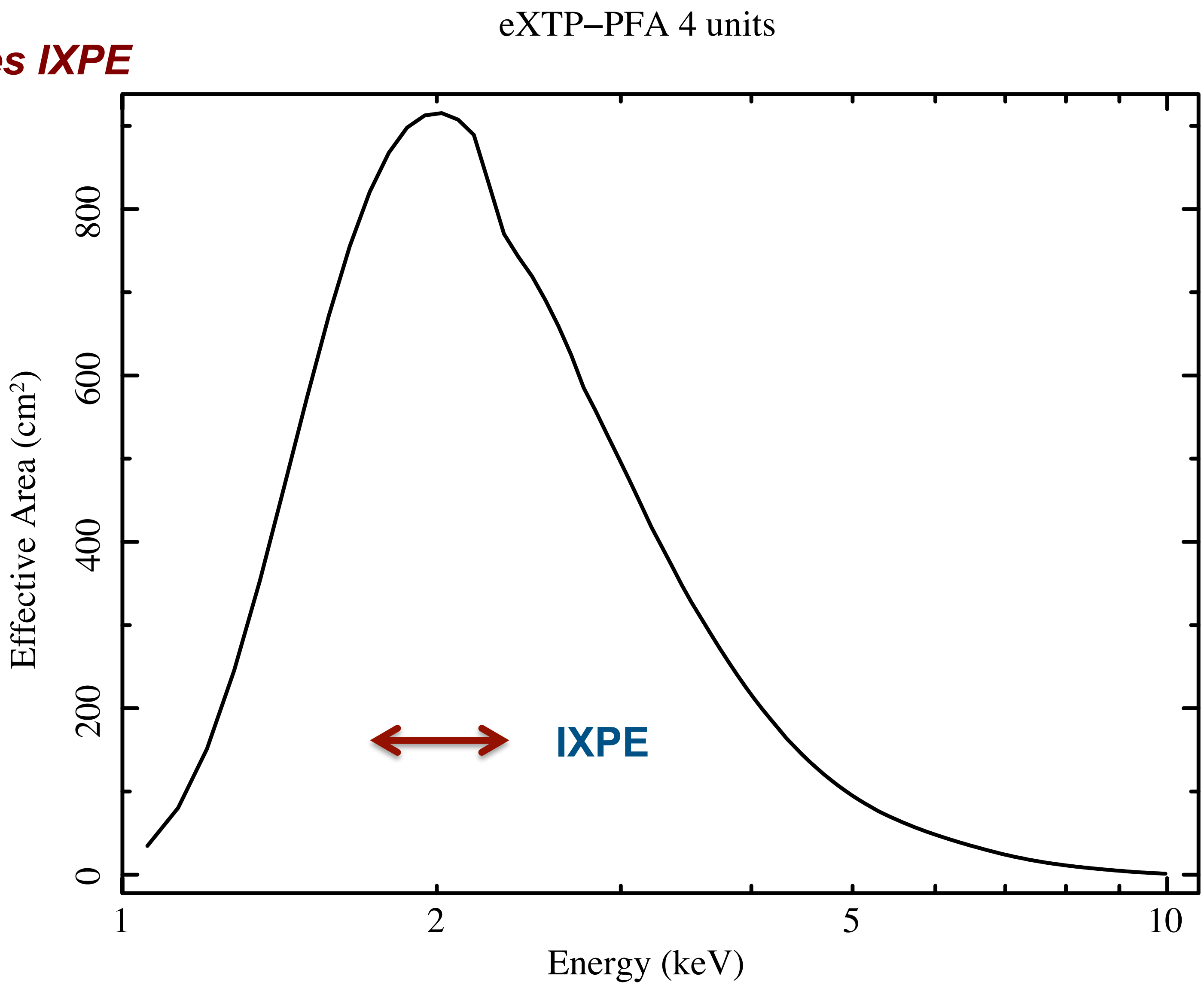
Transformational Mission

Heritage in Europe: Mission concepts highly ranked and widely studied

LOFT + XIPE studies

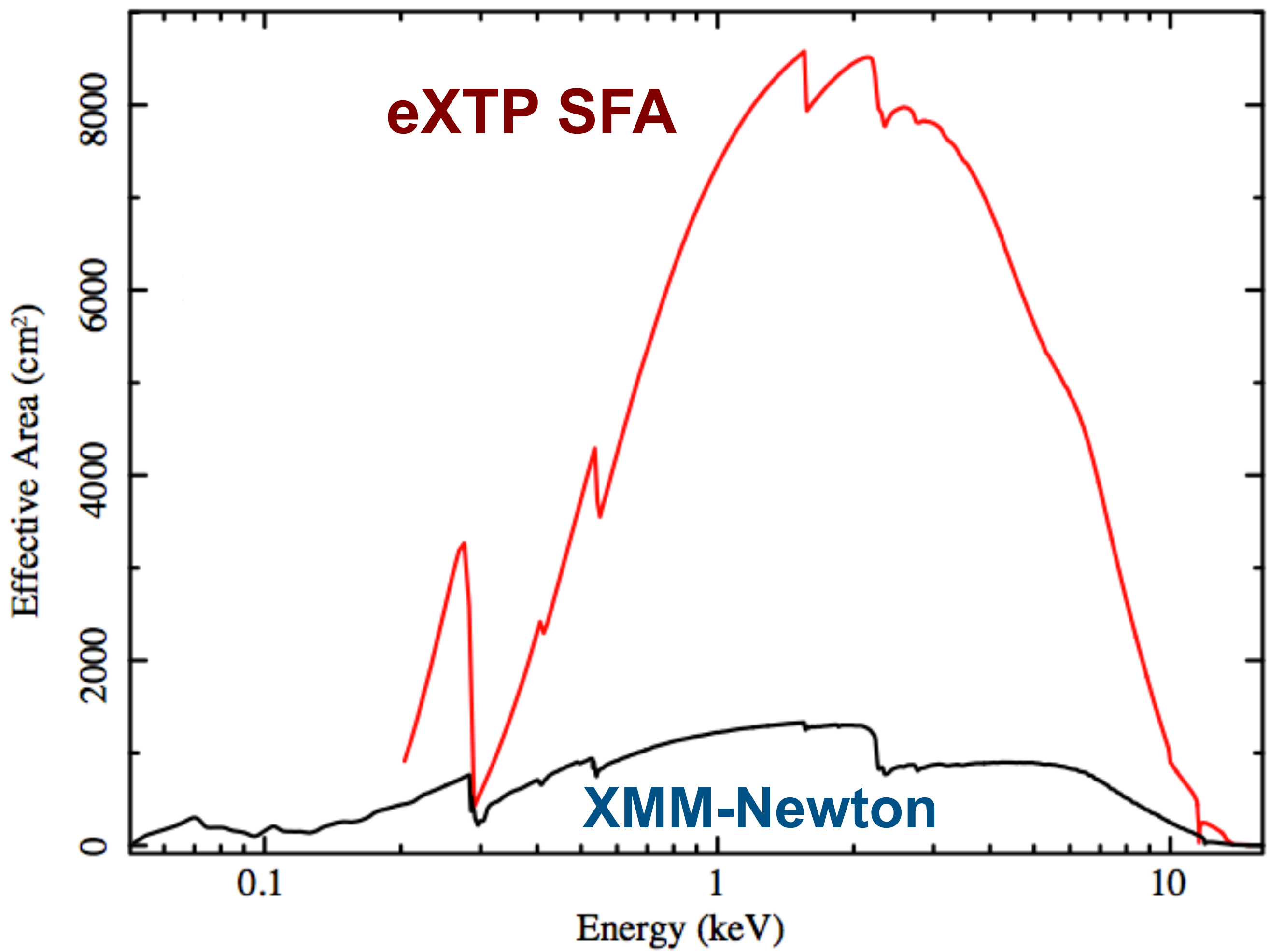
PFA latest area (4 units, new focal length)

5-6 times IXPE



However PFA Baseline: low angular resolution! → move to <30” angular resolution

SFA vs. XMM-Newton- pn



However SFA Baseline: low angular resolution!

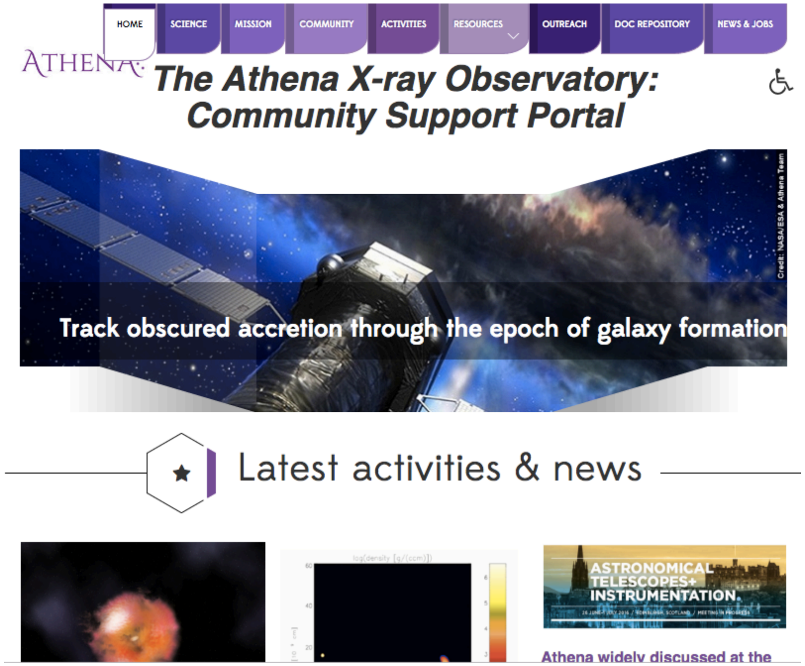
Part II.4

The long term future: ATHENA

ATHENA

Advanced Telescope for High-Energy Astrophysics

- **Second Large (L2) mission of ESA Cosmic Vision 2015-2035**
- **Science theme: The Hot and Energetic Universe**
  - *How does ordinary matter assemble in the large-scale structures?*
  - *How do black holes grow and shape galaxies?*
- In addition:
  - **Fast ToO capability** to study transient sources
  - **Observatory science** across all corners of Astrophysics



More info in:
http://www.the-athena-x-ray-observatory.eu

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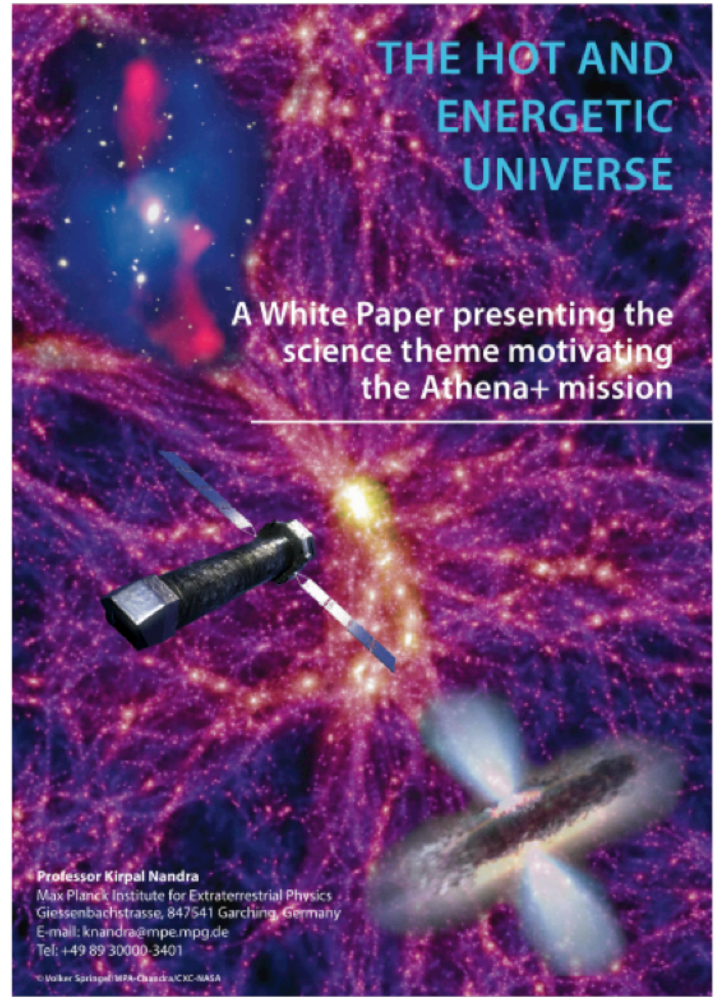
The Hot and Energetic Universe

- *The Hot Universe: How does the ordinary matter assemble into the large-scale structures that we see today?*
  - >50% of the baryons today are in a hot (>10^6 K) phase
  - there are as many hot (> 10^7 K) baryons in clusters as in stars over the entire Universe
- *The Energetic Universe: How do black holes grow and influence the Universe?*
  - Building a SMBH releases 30 × the binding energy of a galaxy
  - 15% of the energy output in the Universe is in X-rays

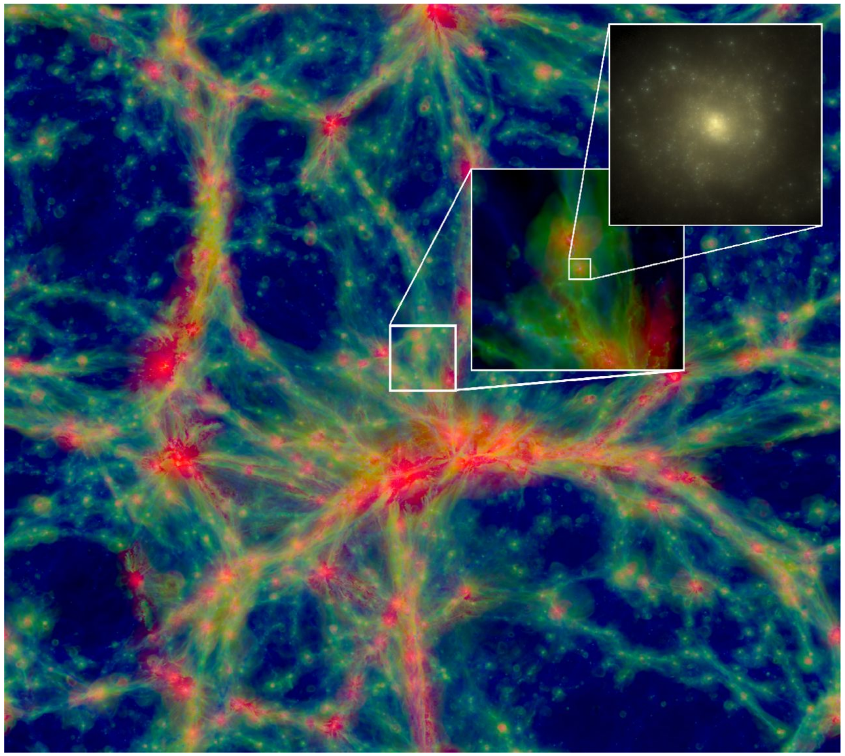


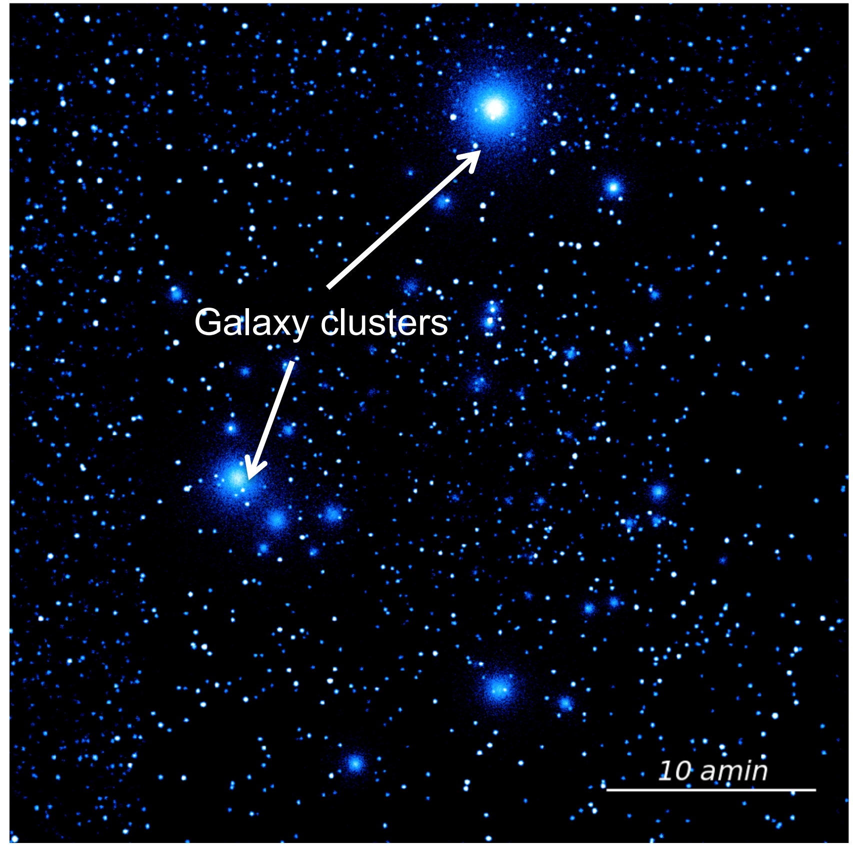
Nandra, Barret, Barcons et al. arXiv:1306.2307

Baryonic assembly

Hot Universe

Schaye et al. 2015



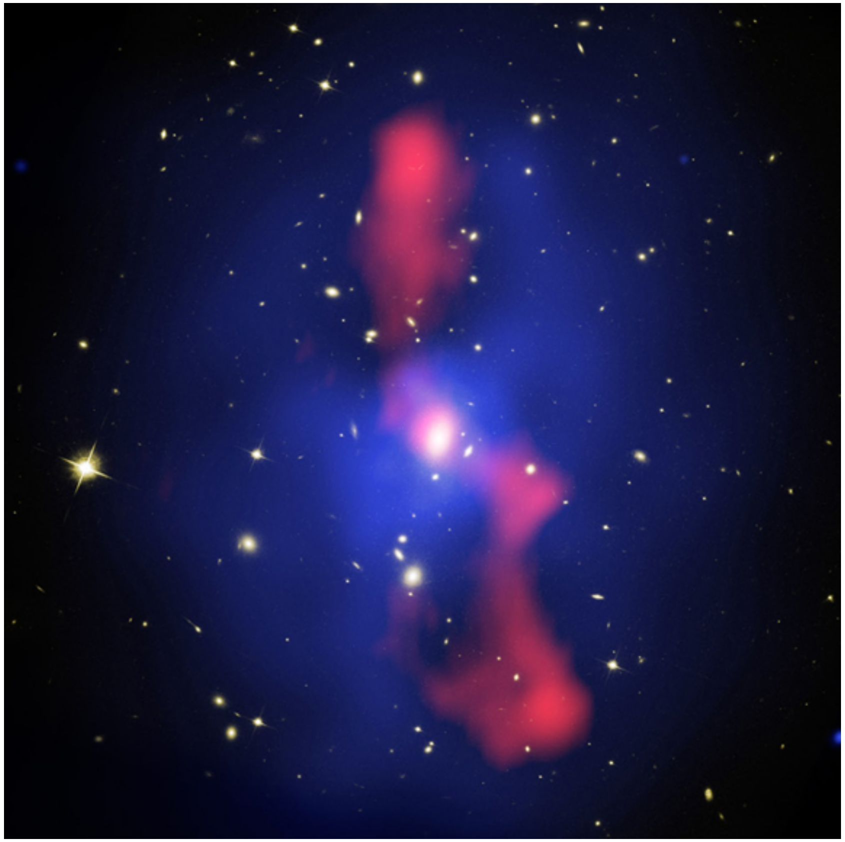


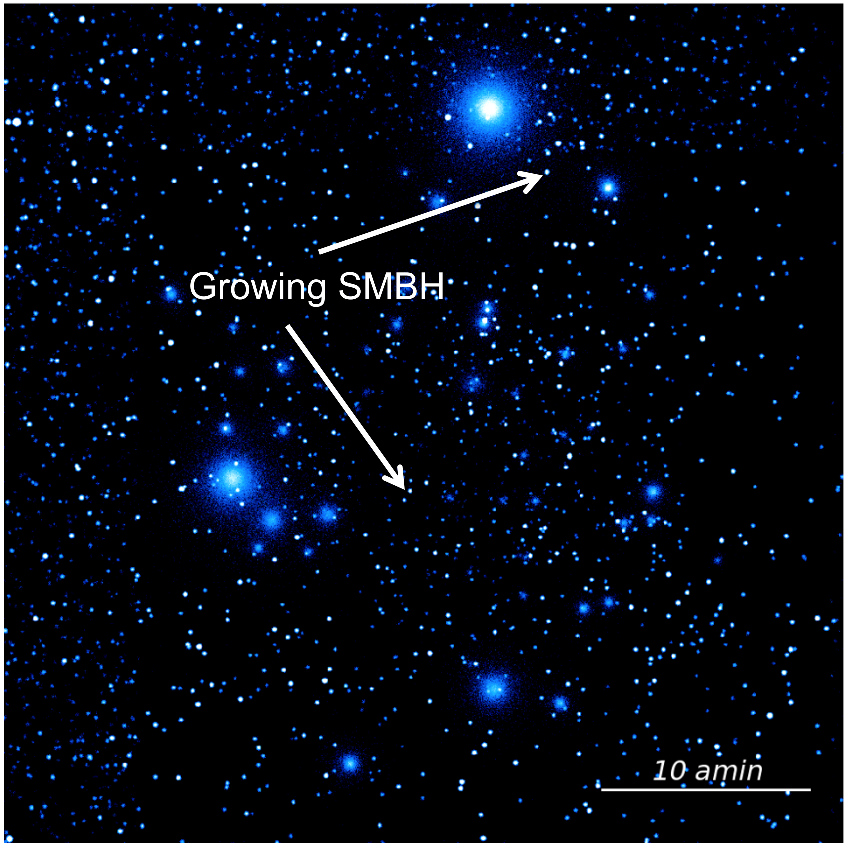
- *First clusters at z>2*
- *Chemical evolution*
- *AGN feedback*
- *Missing baryons*

Athena/WFI 1Ms simulation
MPE & WFI team

Black Holes

Energetic Universe



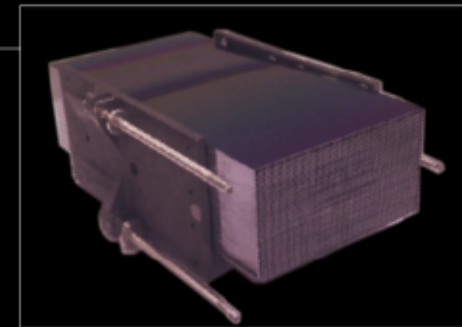


MS0735.6+7421 McNamara et al. 2005

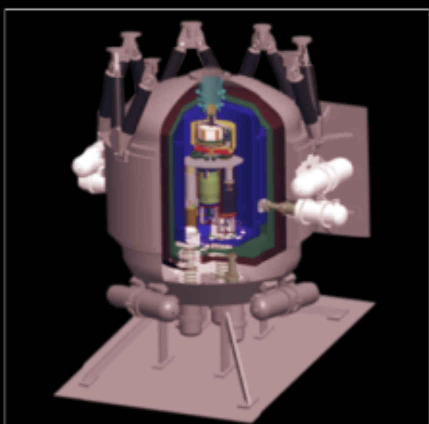
Athena/WFI 1Ms simulation
MPE & WFI team

Willingale et al, 2013
arXiv1308.6785

L2 orbit Ariane V
Mass < 5100 kg
Power 2500 W
>5 year mission

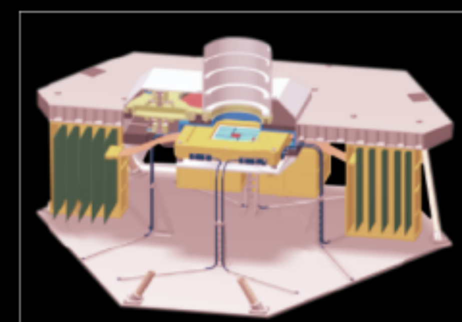


Silicon Pore Optics:
$2\ m^2$ at 1 keV, 0.25 @ 7 keV
5 arcsec HEW
Focal length: 12 m
Sensitivity: $3\ 10^{-17}$ erg $cm^{-2}\ s^{-1}$



X-ray Integral Field Unit:
ΔE: 2.5 eV over 0.5-10 keV
Field of View: 5 arcmin
Operating temp: 50 mk

Barret et al., 2013 arXiv:1308.6784



Wide Field Imager:
ΔE: 125 eV
Field of View: 40 arcmin
High countrate capability

Rau et al. 2013 arXiv1307.1709

Launch 2028, Hexapod switch and defocusing mechanism, Ariane 6, L2 (TBC)

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Conclusions

- TeV Astrophysics and therefore Cosmic Ray studies can benefit from X-ray observation
- X-rays are going to provide key observational information on the physics of the non-thermal Universe and more (thermal emission, lines)
- On the identification of the astrophysical nature of the observed TeV-PeV – atrons.
- Most likely some long-standing puzzles on the nature of the sources of the Cosmic Rays, on the Acceleration Mechanisms, on the nature of the TeV Gamma Binaries will be eventually clarified, by combined TeV and X-ray observations
- However, this is not high in the agenda of the X-ray community.

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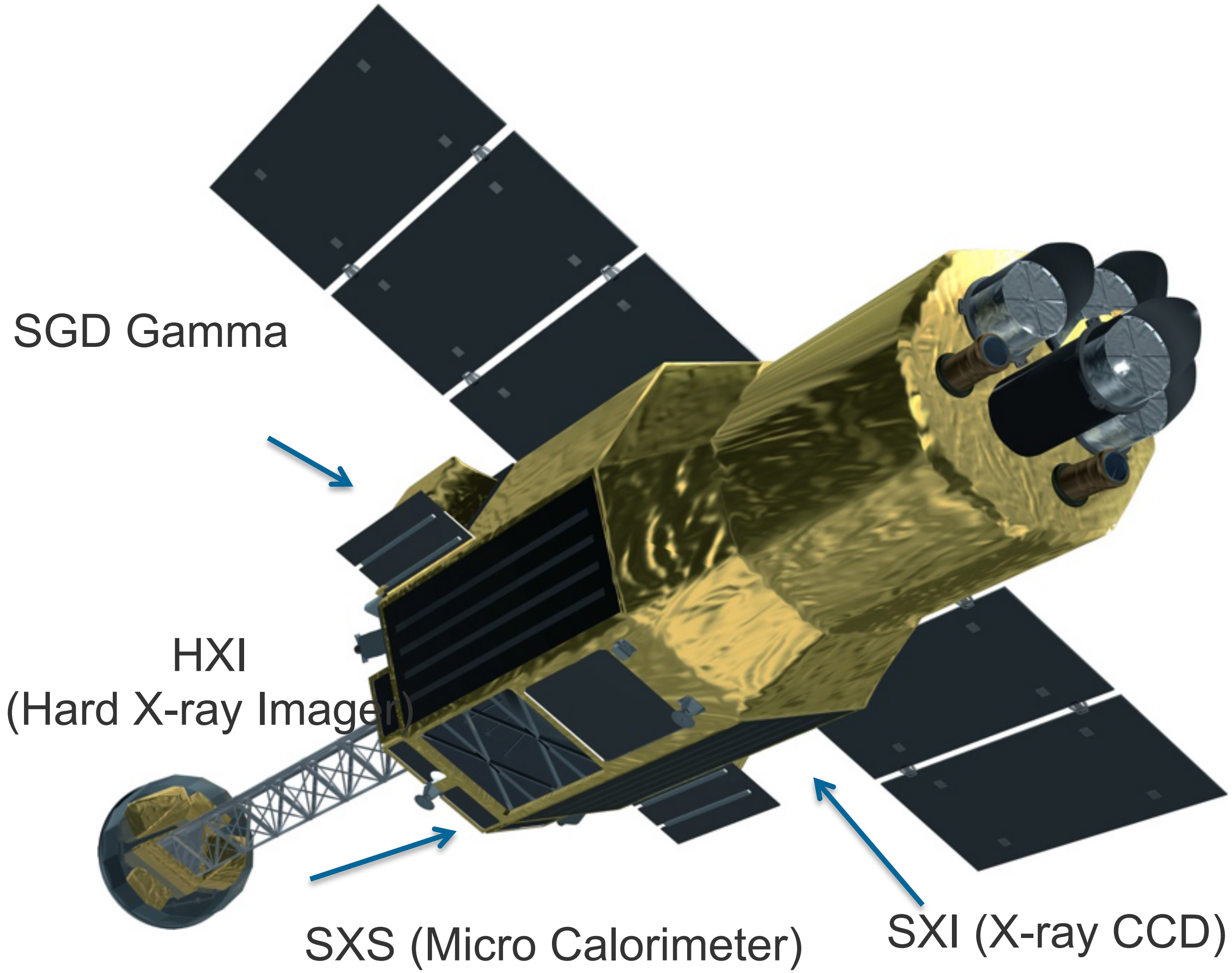
Thank you.

Contact:

Andrea Santangelo
Abteilung Hochenergieastrophysik
Sand 1, 72076 Tübingen · Germany
Phone: +49 7071 29-76128
Andrea.Santangelo@uni-tuebingen.de

Astro-H


SGD Gamma
HXI
(Hard X-ray Imager)
SXS (Micro Calorimeter)
SXI (X-ray CCD)