The Extreme Universe

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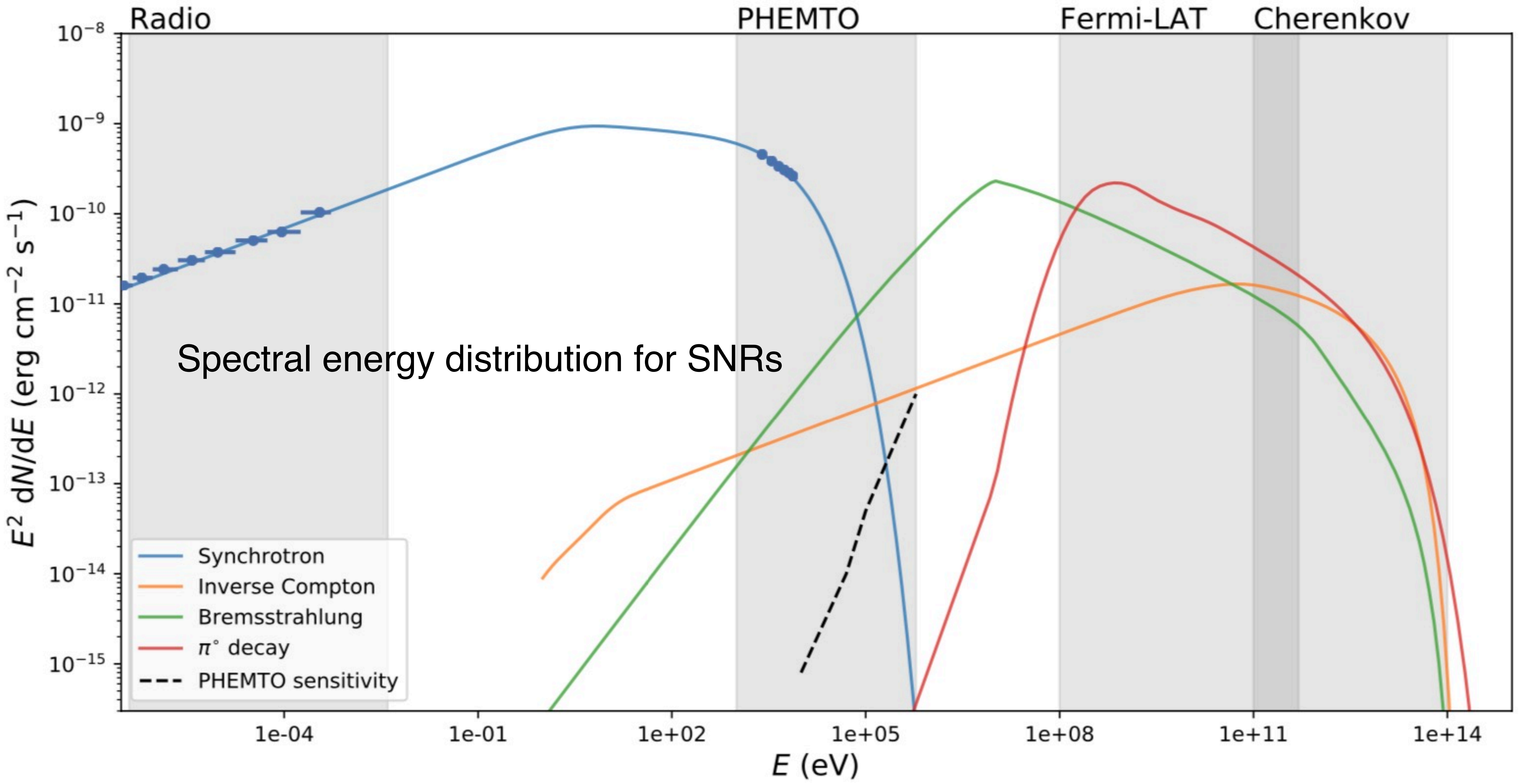
White papers related to the Extreme Universe

- PHEMTO: Polarimetric High Energy Modular Telescope Observatory — Laurent et al.
- A Polarized View of the Hot and Violent Universe — Soffitta et al.
- Gamma-ray Astrophysics in the MeV Range; The ASTROGAM Concept and Beyond — De Angelis et al.
- Understanding the origin of the positron annihilation line and the physics of the supernova explosions — Frontera et al.
- A Deep Study of the High–Energy Transient Sky — Guidorzi et al. [Presentation]
- GrailQuest: hunting for Atoms of Space and Time hidden in the wrinkle of Space–Time — Burderi et al.
- THEZA: TeraHertz Exploration and Zooming-in for Astrophysics — Gurvits et al.
- The Voyage of Metals in the Universe from Cosmological to Planetary Scales — Nicastro & Kaastra et al.
- Voyage through the Hidden Physics of the Cosmic Web — Simionescu et al. [Presentation]
- The high energy universe at ultra-high resolution: the power and promise of X-ray interferometry — Uttley et al. [Presentation]

PHEMTO: Polarimetric High Energy Modular Telescope Observatory — Laurent et al.

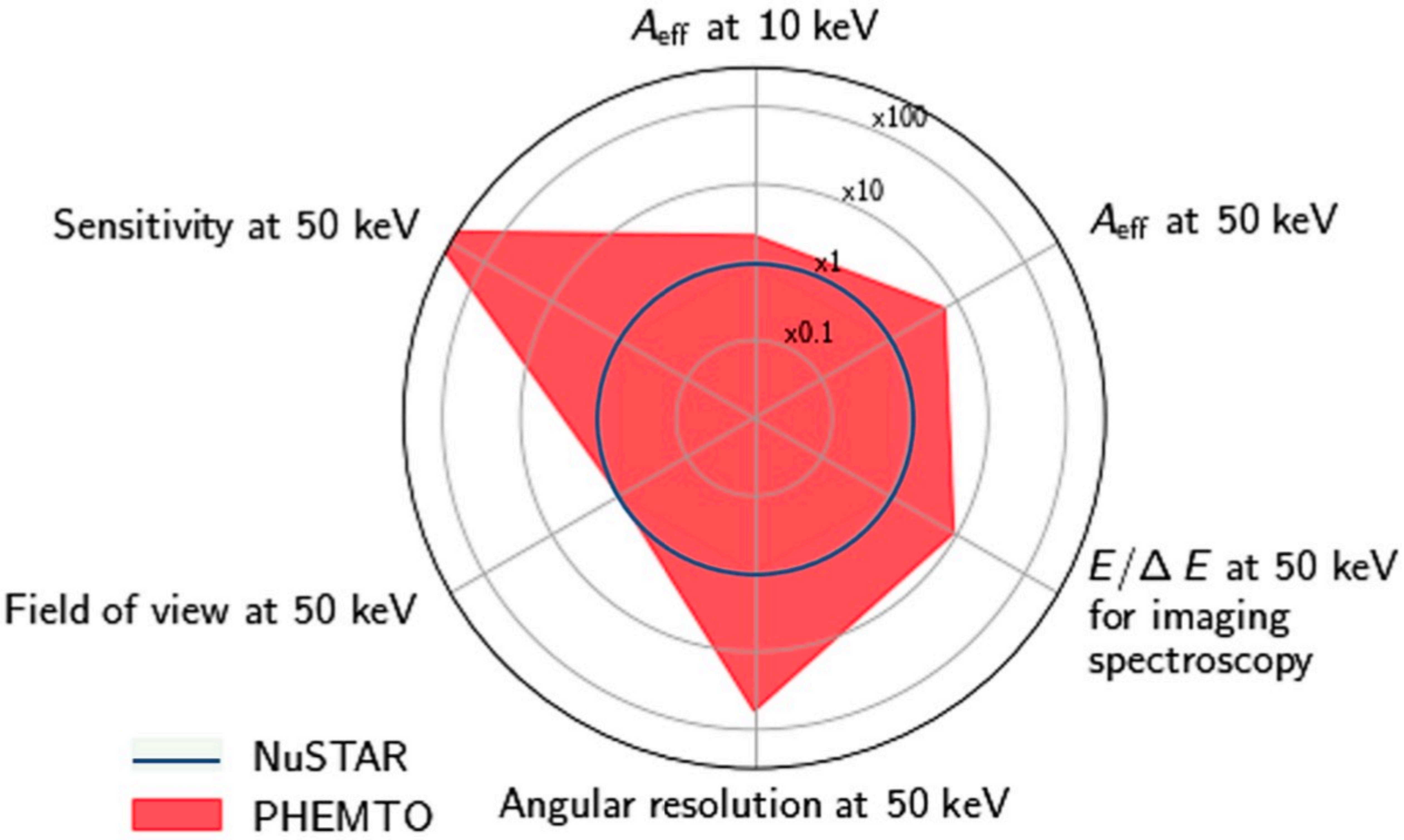
- Black Hole Census, Cosmic X-Ray Background and obscured accreting AGN
- Constraining explosion physics in supernovae and their remnants
- The role of magnetic fields in cosmic accelerators and compact objects
- Accretion and ejection physics
- Hard X-ray emission of galaxy clusters

An observatory to map the hard x-ray polarized sky with arcsecond accuracy



PHEMTO: Polarimetric High Energy Modular Telescope Observatory — Laurent et al.

- Hard x/γ-ray satellite with two telescopes.
- Lower energy:
  - focusing mirrors, very long focal length (up to 100m)
  - silicon monolithic imager (1-40keV).
- Higher energies:
  - Laue lens
  - CdTe detector (8-600keV)



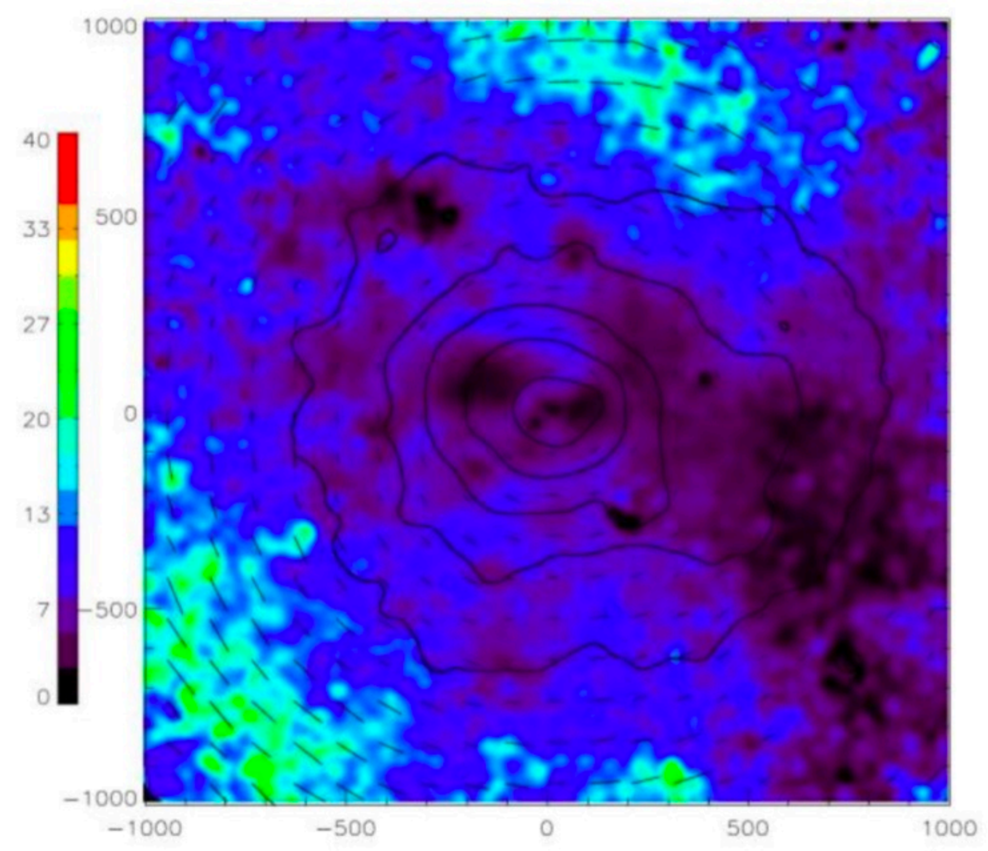
A polarized view of the hot and violent universe — Soffitta et al.

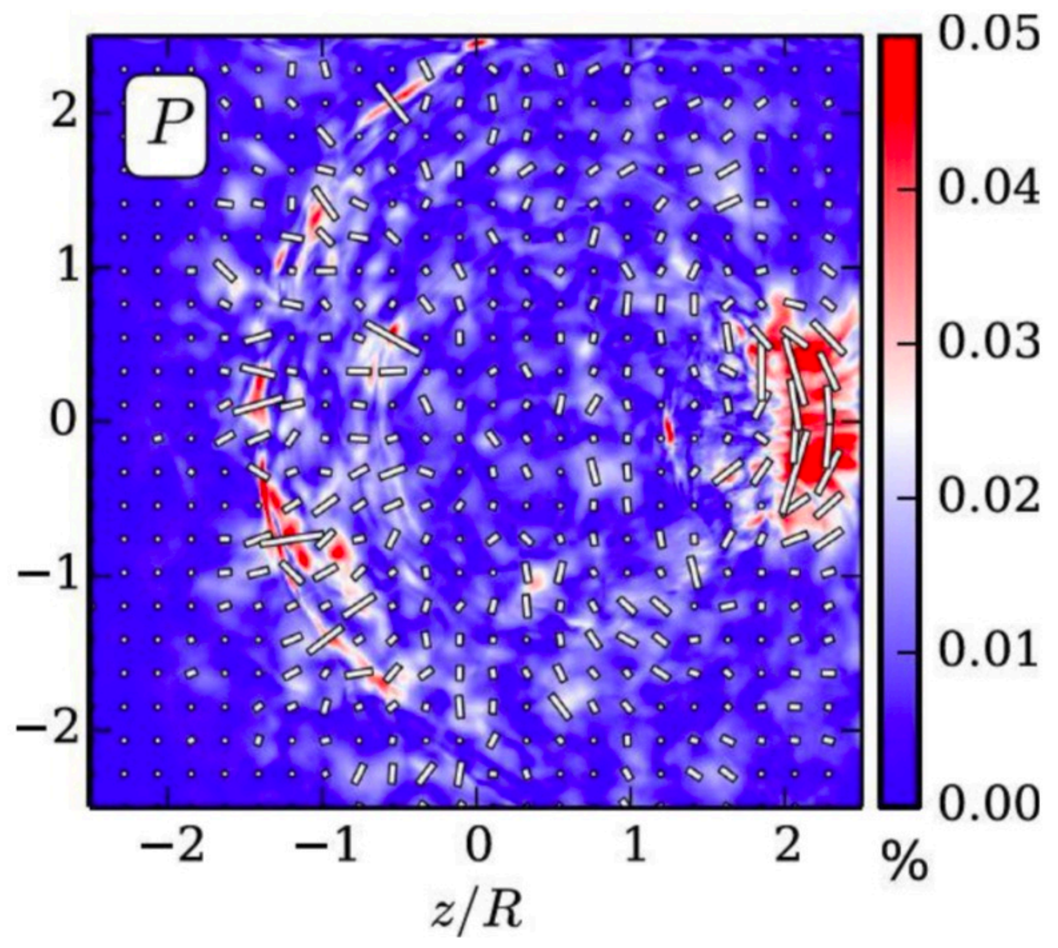
NGXP: Next Generation X-ray Polarimetry mission

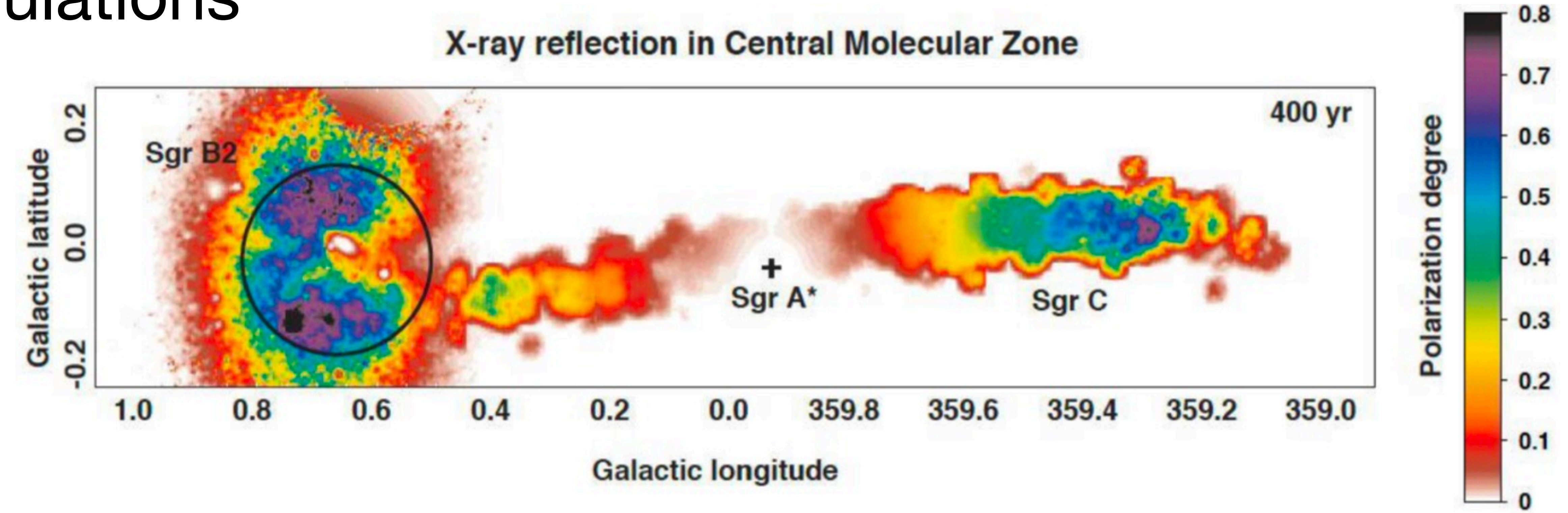
- Extended sources: PWNe, SNRs, galaxy clusters
- Compact Objects: accreting neutron stars and stellar-mass black holes, Magnetars; GRBs; AGN; SGR A* and the Galactic Center

Planned missions IXPE and eXTP: (2–8 keV; 25” resolution, <1000 cm^2; narrow FoV) . Need:

- Broader band (0.1-100 keV): Polarization of different spectral components & energy-dependent diagnostics
- Wide Field: Transients (incl. prompt GRBs)
- Better eff. area (5000 cm^2) and ang. res. (5")
  - Finer details in PWNe & SNRs
  - Temporal studies in compact objects
  - Populations

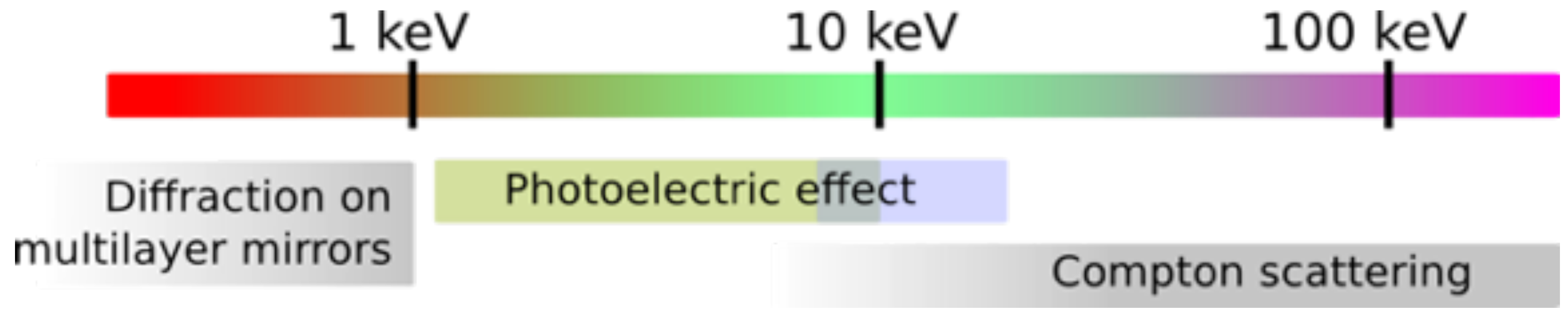






A polarized view of the hot and violent universe — Soffitta et al.

- 2–8 keV & Hard X-ray Polarimeters (imaging Gas Pixel Detectors)
- Broad Band Polarimeter (non-imaging. Multilayer mirror; TPC-polarimeter; Compton polarimeter)
- Gamma-ray bursts & transient polarimeter (non-imaging. Compton scattering, plastic scintillators and Si-PMT)
- Wide Field Camera (0.2–2 keV and/or 2–50 (Si Drift Detectors or Lobster Eye)

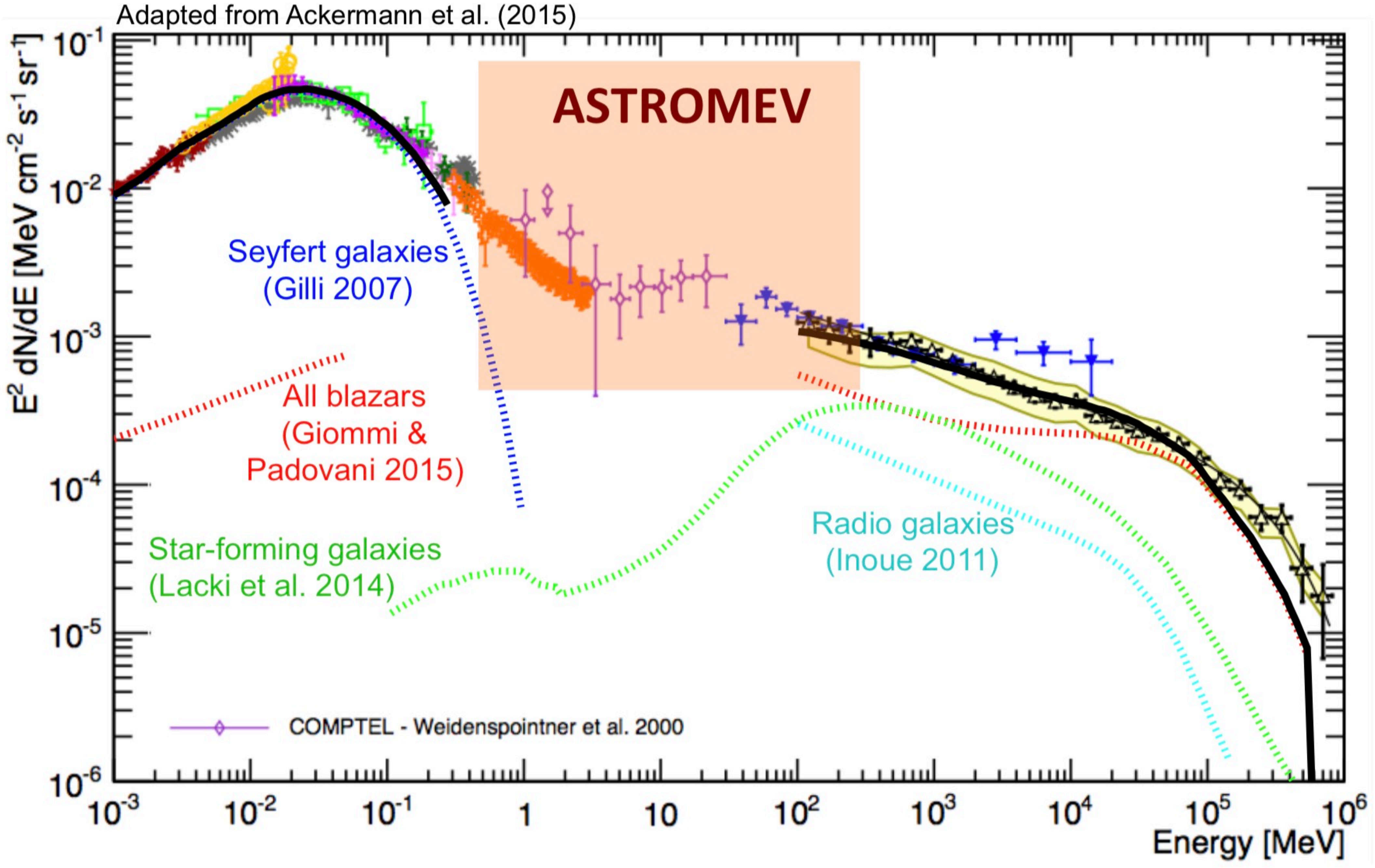


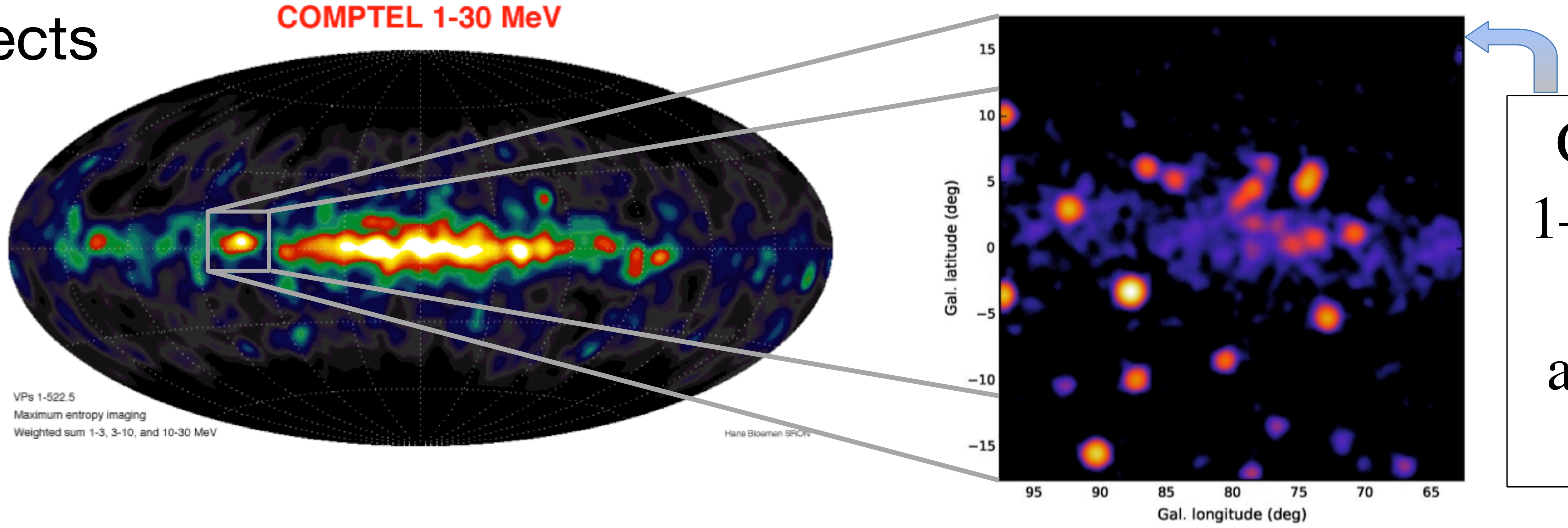
Multi-telescope system is needed

Telescopes	Imaging	#	0.2	2-8	6-25	15-80
Classical Range Energy Polarimeter	Y	2		X		
Hard X-ray Energy Polarimeter	Y	2			X	
Broad Band Polarimeter	N	4	X	X	X	X
Wide Field Instruments						
Wide Field Camera	Y	4				
Transient Sources Polarimeter	N	2				

Gamma-ray Astrophysics in the MeV Range
The ASTROGAM Concept and Beyond — De Angelis et al.

- Extragalactic (GRBs, clusters of galaxies, MeV background, MMA, e.g. KN lines up to 10Mpc)
- Origin and impact of cosmic rays
- Explosive nucleosynthesis and chemical evolution of the Galaxy
- Observatory science in the MeV domain
    - Physics of compact objects
    - Solar and Earth science
    - Fundamental physics





Cygnus region in 1–30 MeV with the ASTROMEV angular resolution and sensitivity

Gamma-ray Astrophysics in the MeV Range
The ASTROGAM Concept and Beyond — De Angelis et al.

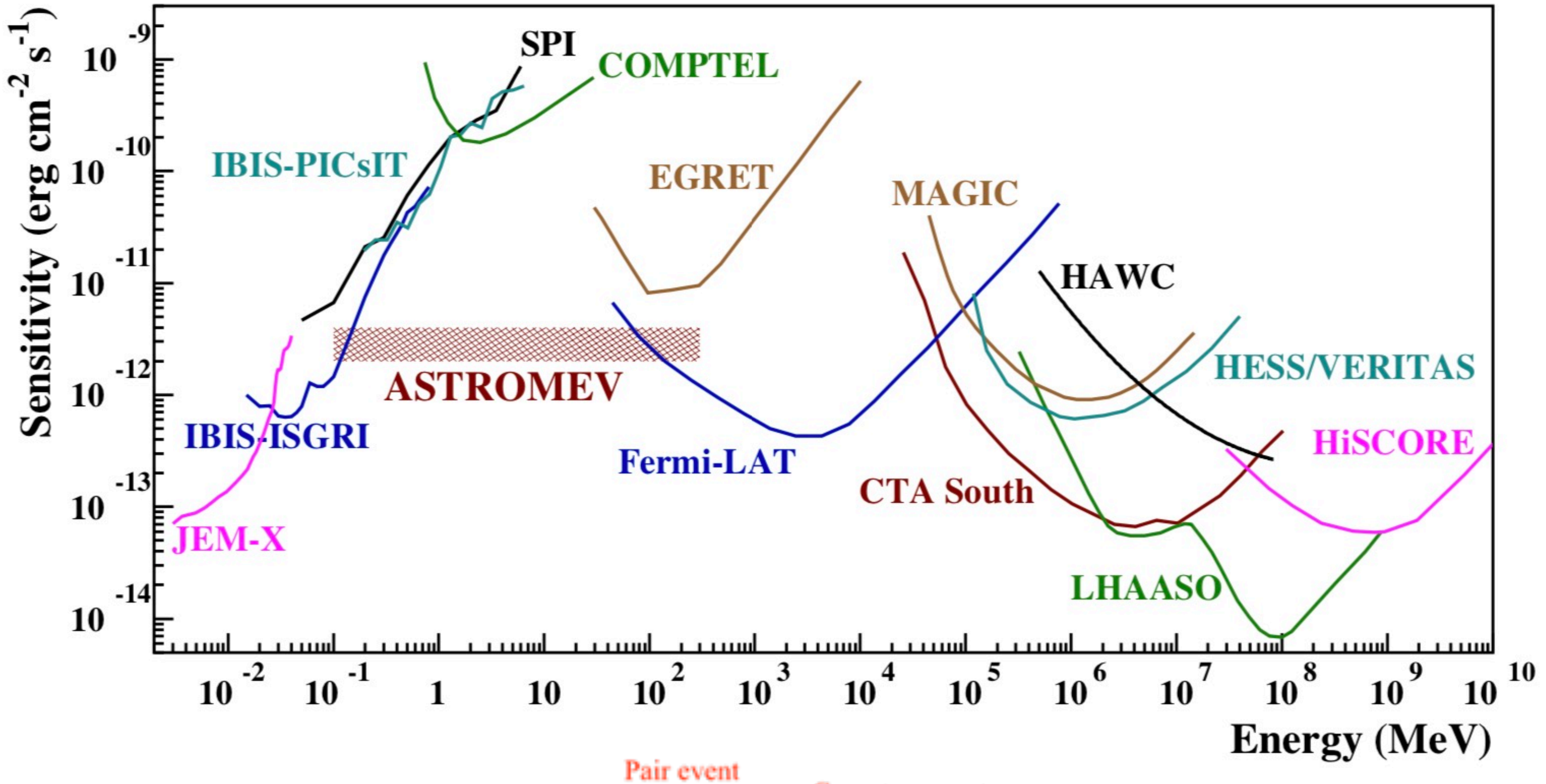
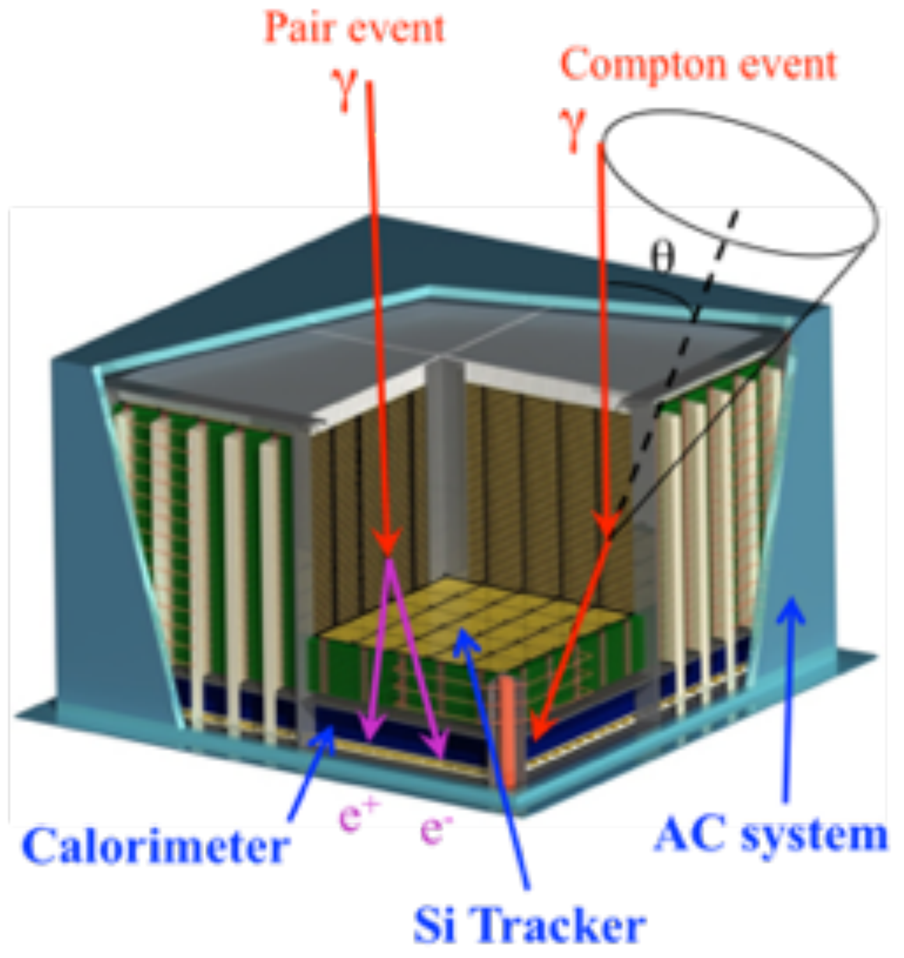


Table 2: Required instrument performance to achieve the core science objectives

Parameter	Value
Spectral range	100 keV – 1 GeV
Field of view	≥ 2.5 sr
Continuum flux sensitivity for 10^6 s observation time (3σ confidence level)	$< 2 \times 10^{-5}$ MeV cm^2 s^1 at 1 MeV (any source) $< 5 \times 10^{-5}$ MeV cm^2 s^1 at 10 MeV (high-latitude source) $< 3 \times 10^{-6}$ MeV cm^2 s^1 at 500 MeV (high-latitude source)
Line flux sensitivity for 10^6 s observation time (3σ confidence level)	$< 5 \times 10^{-6}$ ph cm^2 s^1 for the 511 keV line $< 5 \times 10^{-6}$ ph cm^2 s^1 for the 847 keV SN Ia line $< 3 \times 10^{-6}$ ph cm^2 s^1 for the 4.44 MeV line from LECRs
Angular resolution	$\leq 1.5°$ at 1 MeV (FWHM of the angular resolution measure) $\leq 1.5°$ at 100 MeV (68% containment radius) $\leq 0.2°$ at 1 GeV (68% containment radius)
Polarisation sensitivity	Minimum Detectable Polarisation < 20% (99% confidence level) for a 10 mCrab source in $T_{\rm obs} = 10^6$ s ($\Delta E = 0.1 - 2$ MeV)
Spectral resolution	$\Delta E/E = 3\%$ at 1 MeV $\Delta E/E = 30\%$ at 100 MeV
Time tagging accuracy	1 microsecond (at 3σ)



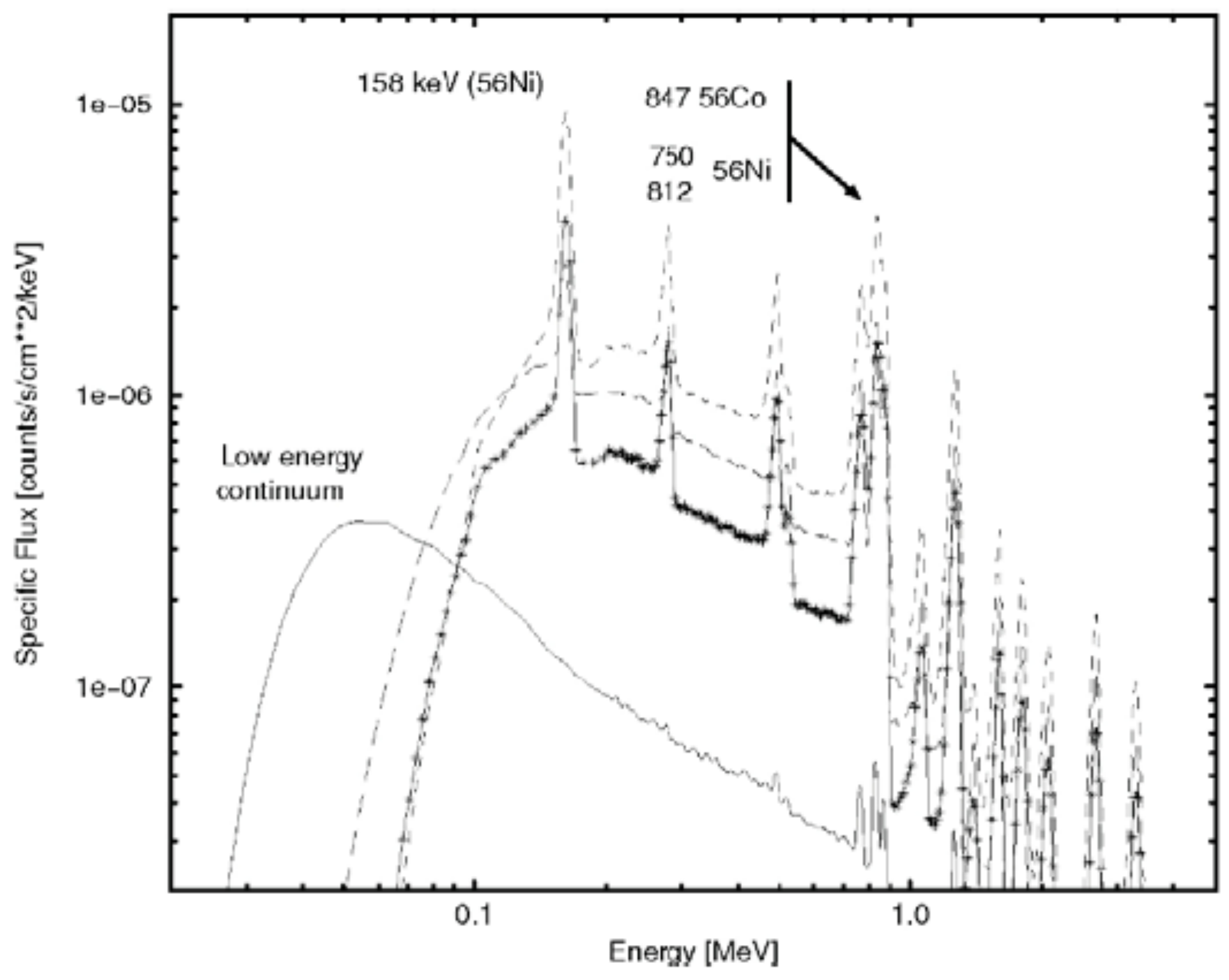
Take advantage of recent progress in silicon detectors and readout microelectronics to substantially improve sensitivity, angular resolution and polarimetric capability

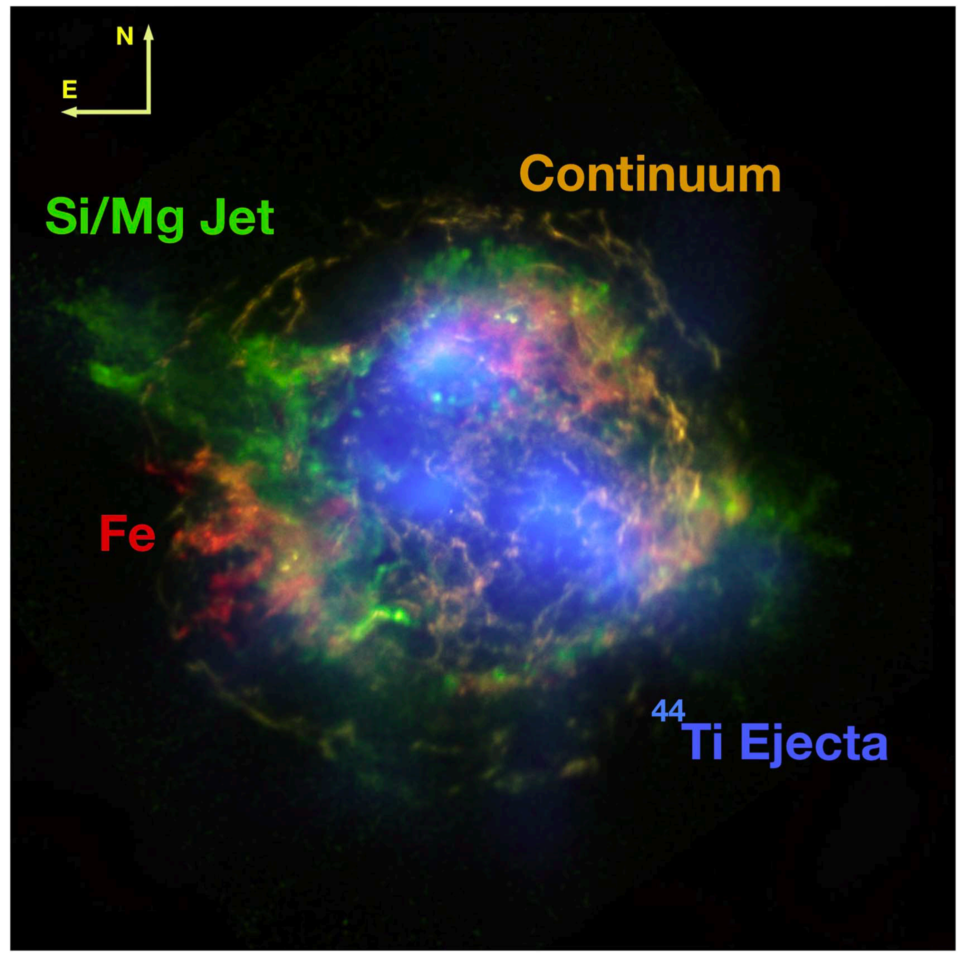
Understanding the origin of the positron annihilation line and the physics of the supernova explosions — Frontera et al.

- Origin of 511 keV positron annihilation line from the Galactic Center region

- Line emission from radioactive nuclei produced in supernova explosions: Ia (physics of the Phillips relation) and core-collapse (explosion mechanism and potential asymmetries in CCSNe) and CVs

Gomez-Gomar+1998

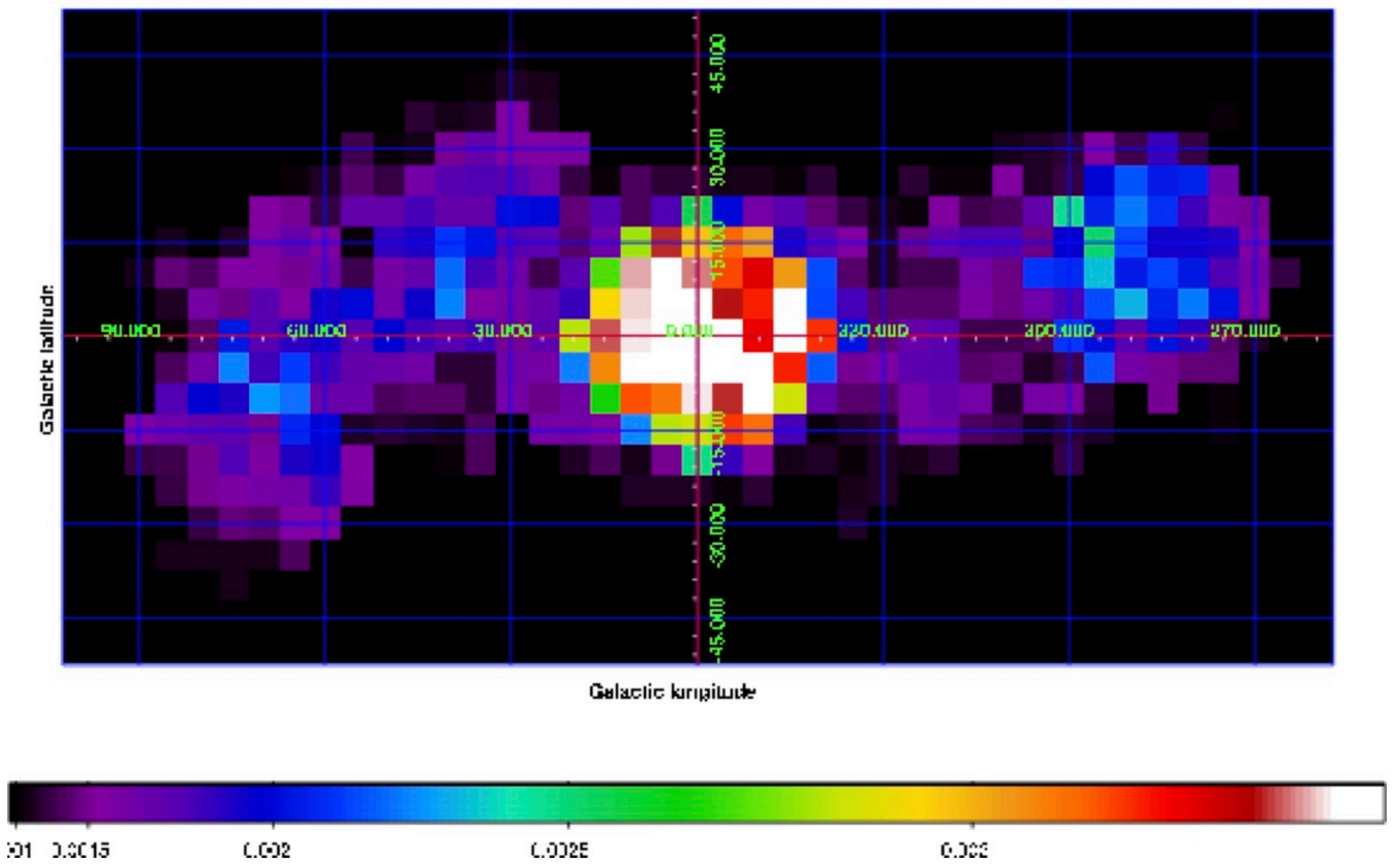




Grefenstette+2017
44Ti from NuSTAR
other from Chandra

ASTENA: *Advanced Surveyor of Transient Events and Nuclear Astrophysics (see Guidorzi talk). 2keV–20MeV wide-field monitor, 50-600keV narrow field telescope*

Bouchet+2010

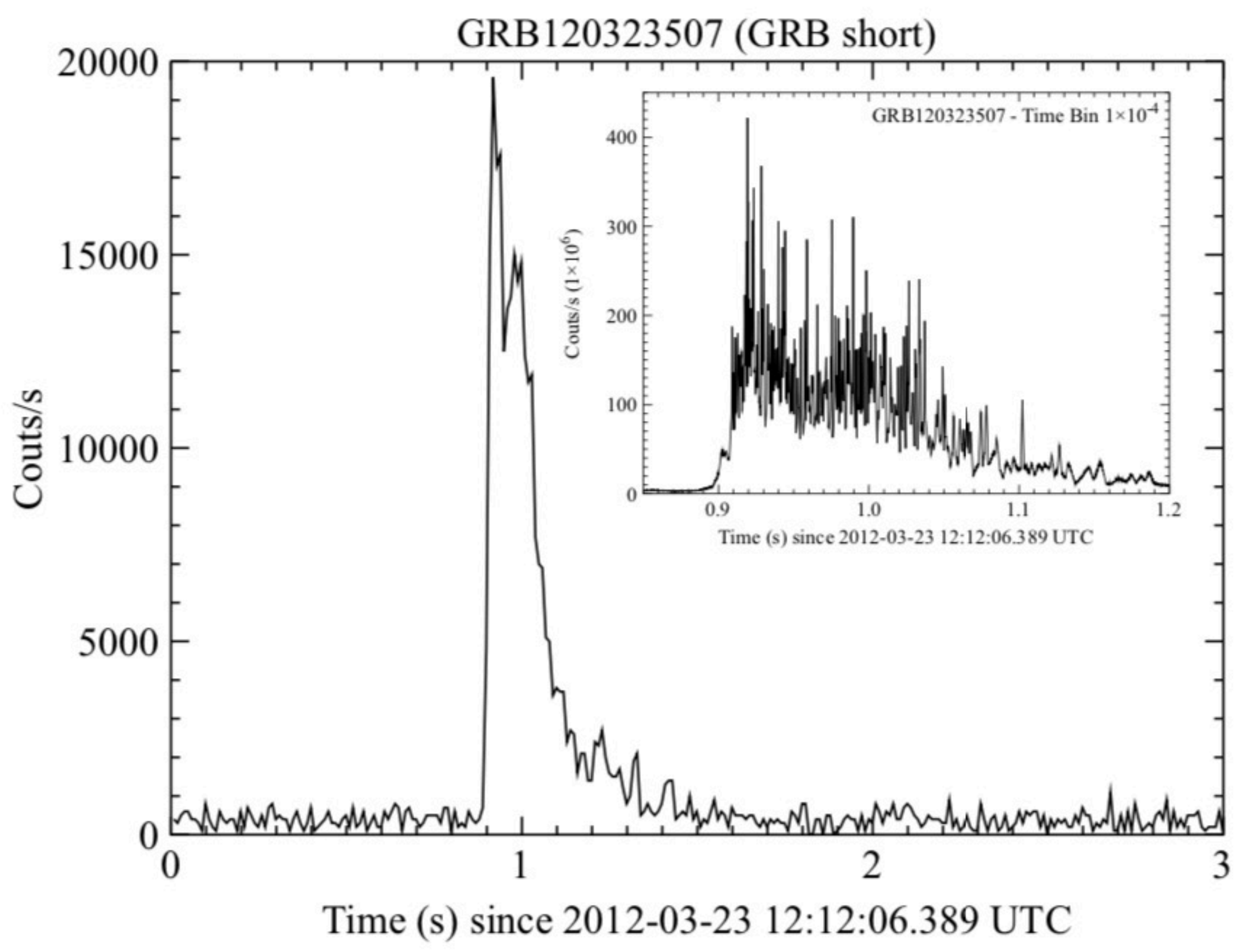


GrailQuest: hunting for Atoms of Space and Time hidden in the wrinkle of Space–Time — Burderi et al.

- Probe space-time structure down to the Planck-scale by measuring delays between photons of different energies in Gamma Ray Bursts (GRBs)

- Localise GRB prompt emission within a few arc-seconds (particular relevance to fast high energy transients connected to gravitational wave events)

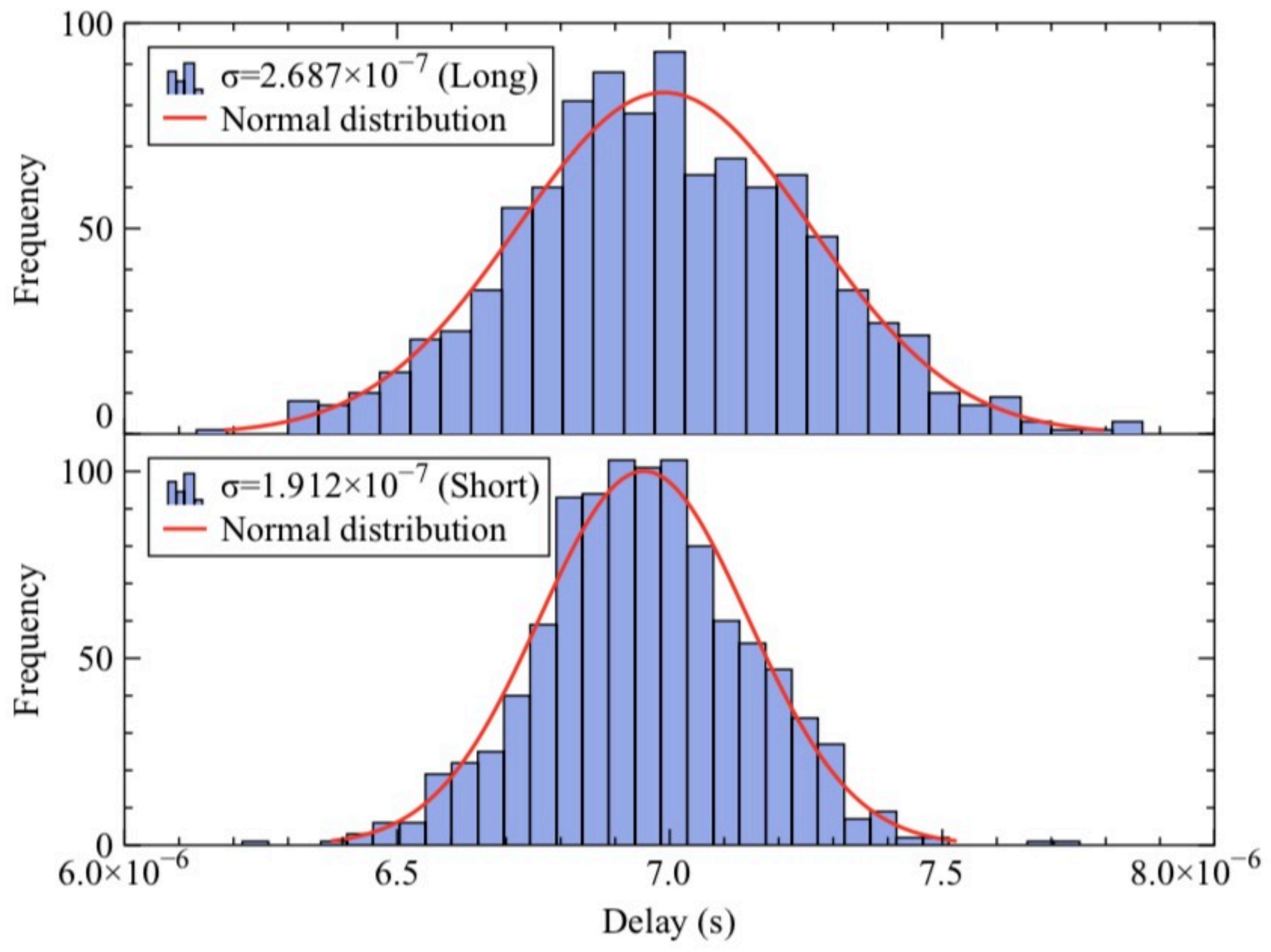
- Exploit timing capabilities down to micro–seconds or below in x/γ–rays to investigate the micro-second structure of GRBs and other transients

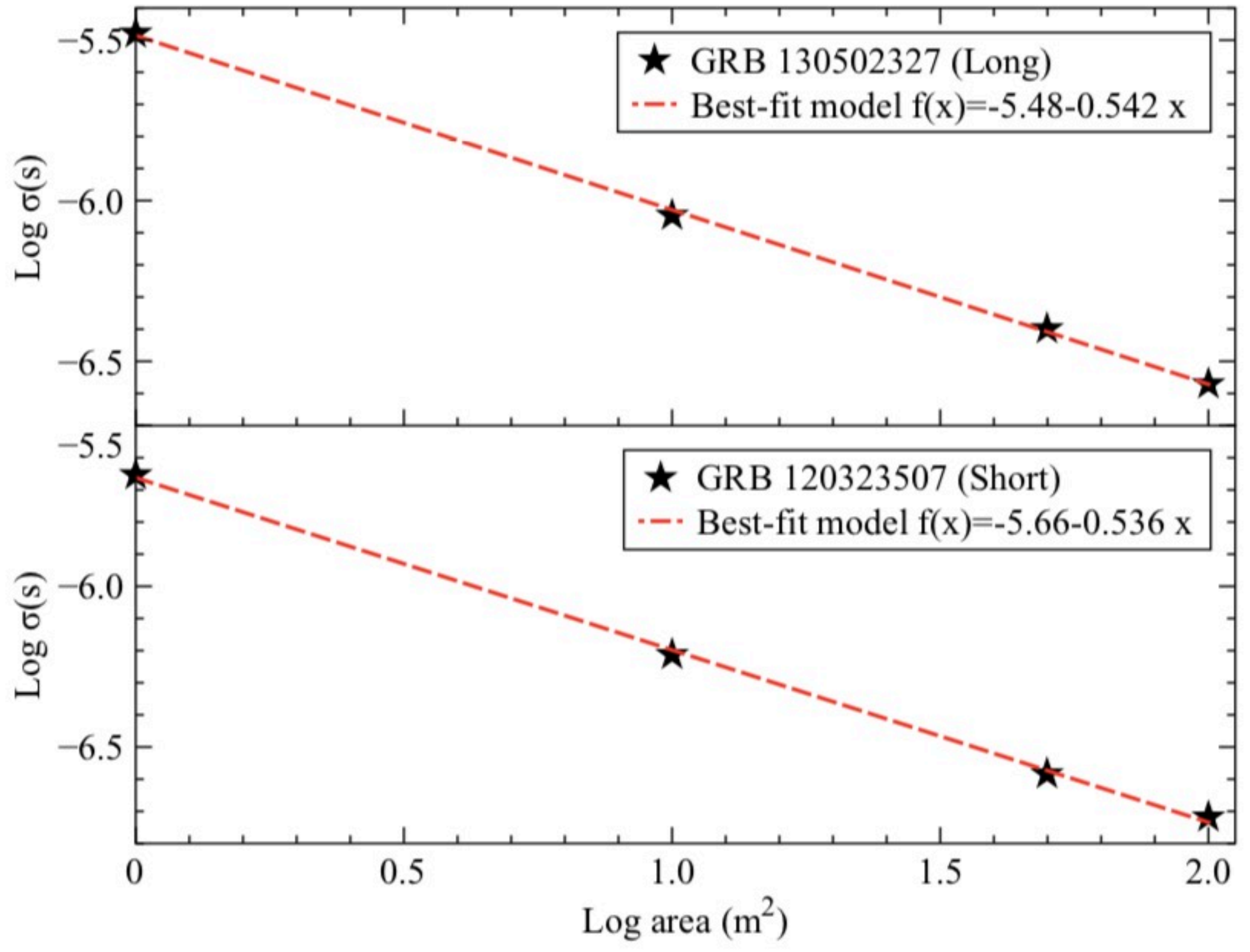


Quantum gravity experiment

Space-Time granular structure $l_P \sim 10^{-33}$ cm

Dispersion law for photons $v_{ph}/c \sim [1 - l_P/\lambda_{ph}]$

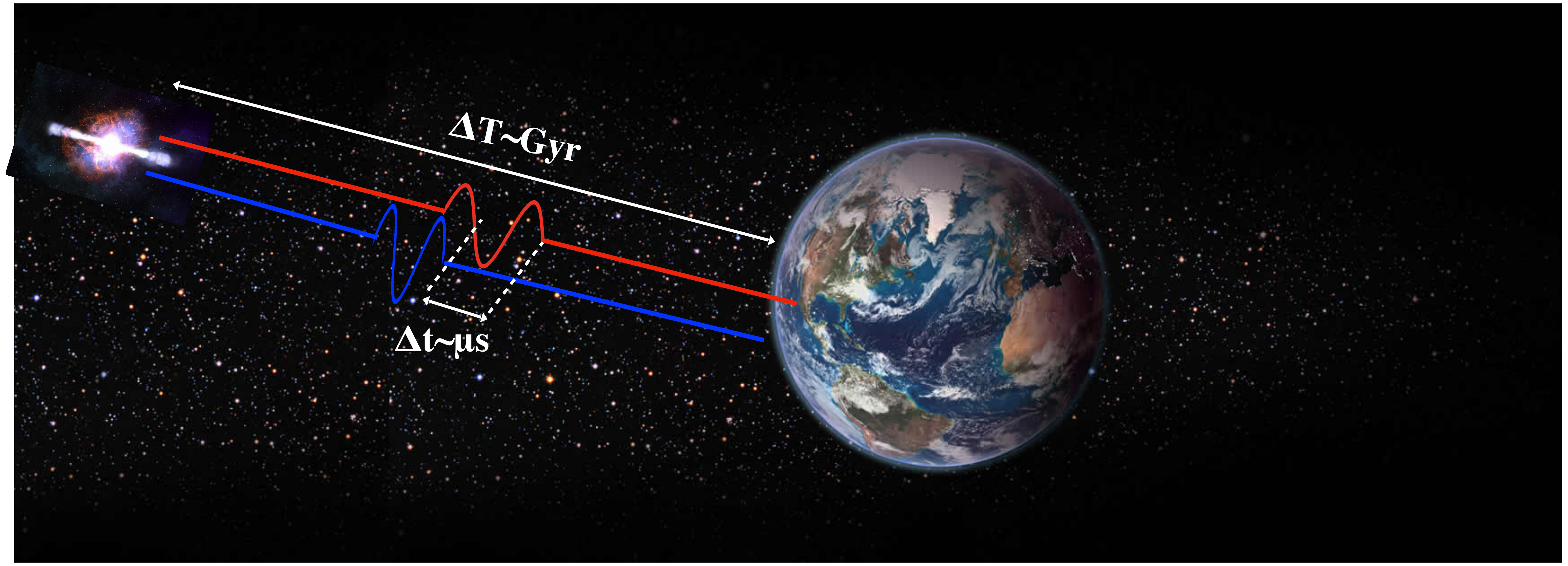




GrailQuest: hunting for Atoms of Space and Time hidden in the wrinkle of Space–Time — Burderi et al.

A swarm of nano/micro/small–satellites to probe the ultimate structure of Space-Time and to provide an all-sky monitor to study high energy astrophysics phenomena

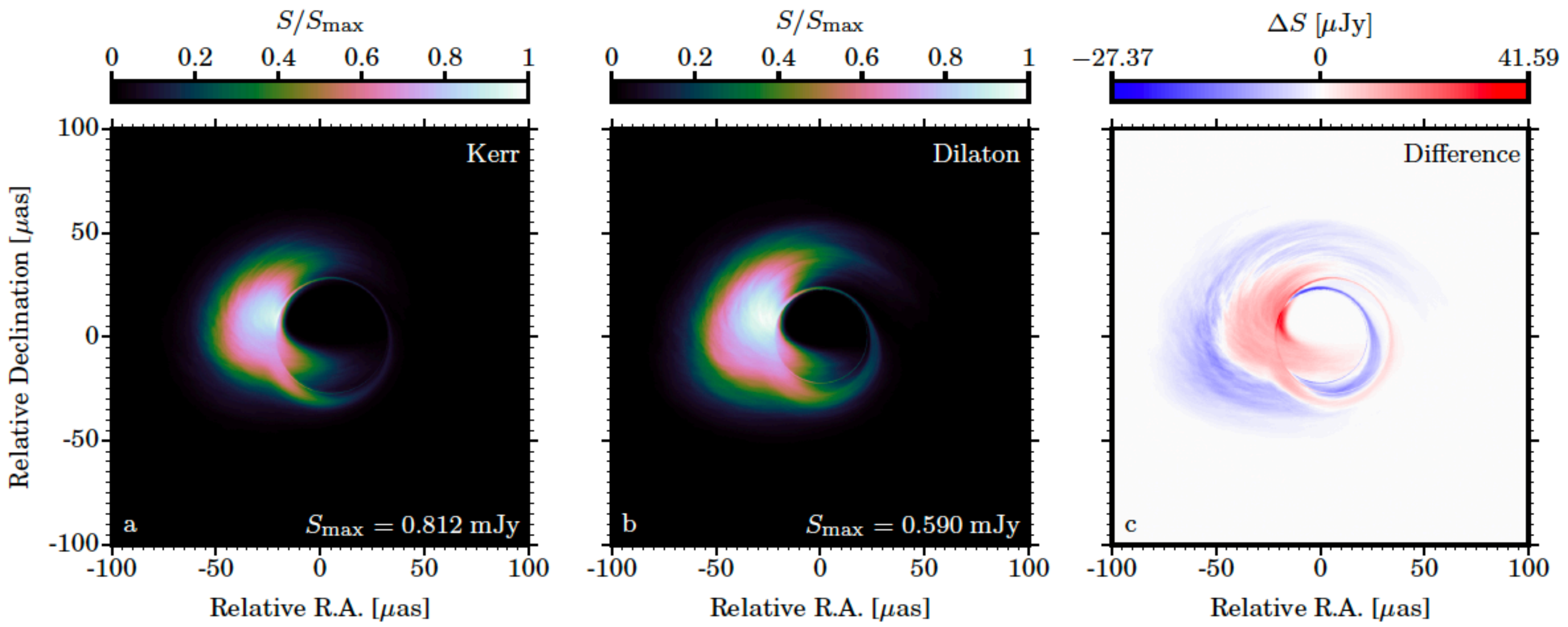
- Constellation of 100–10000 small satellites
- Total collecting area ~100 m2
- keV-MeV energy band
- Time resolution < 100 ns
- Mass production, Assembly line, Cost reduction



THEZA: TeraHertz Exploration and Zooming-in for Astrophysics — Gurvits et al.

- Physics of the event horizon of the Galaxy's supermassive black hole (Sgr A*)
- SMBHs in other galaxies. Unique opportunity to peer into exospheres of (many) black holes
- Inner jets in active galactic nuclei (AGN)
- Evolutionary properties of binary AGN – precursors to gravitational wave events
- Synergistic studies of astrophysical transients
- Search for water maser emission in the interstellar medium and protoplanetary discs
- Studies of exoplanets
- Search for technosignatures – extraterrestrial civilisations

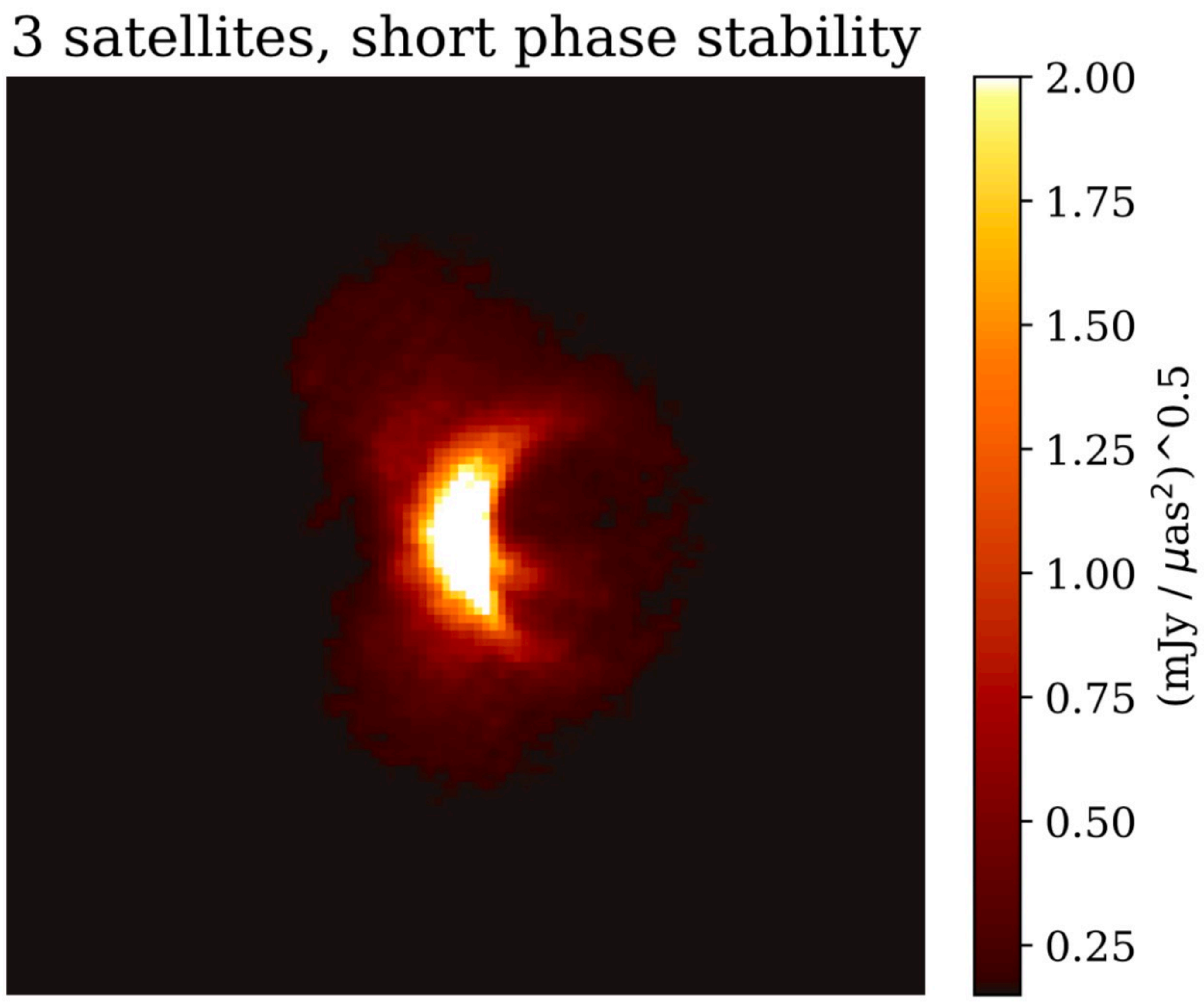
radio/mm/sub-mm inteferometric system for (sub-)micro-arcseconds imaging



Simulations of a Kerr black hole (left) versus non-rotating BH (middle) and their difference (right), Mizuno+2018

THEZA: TeraHertz Exploration and Zooming-in for Astrophysics — Gurvits et al.

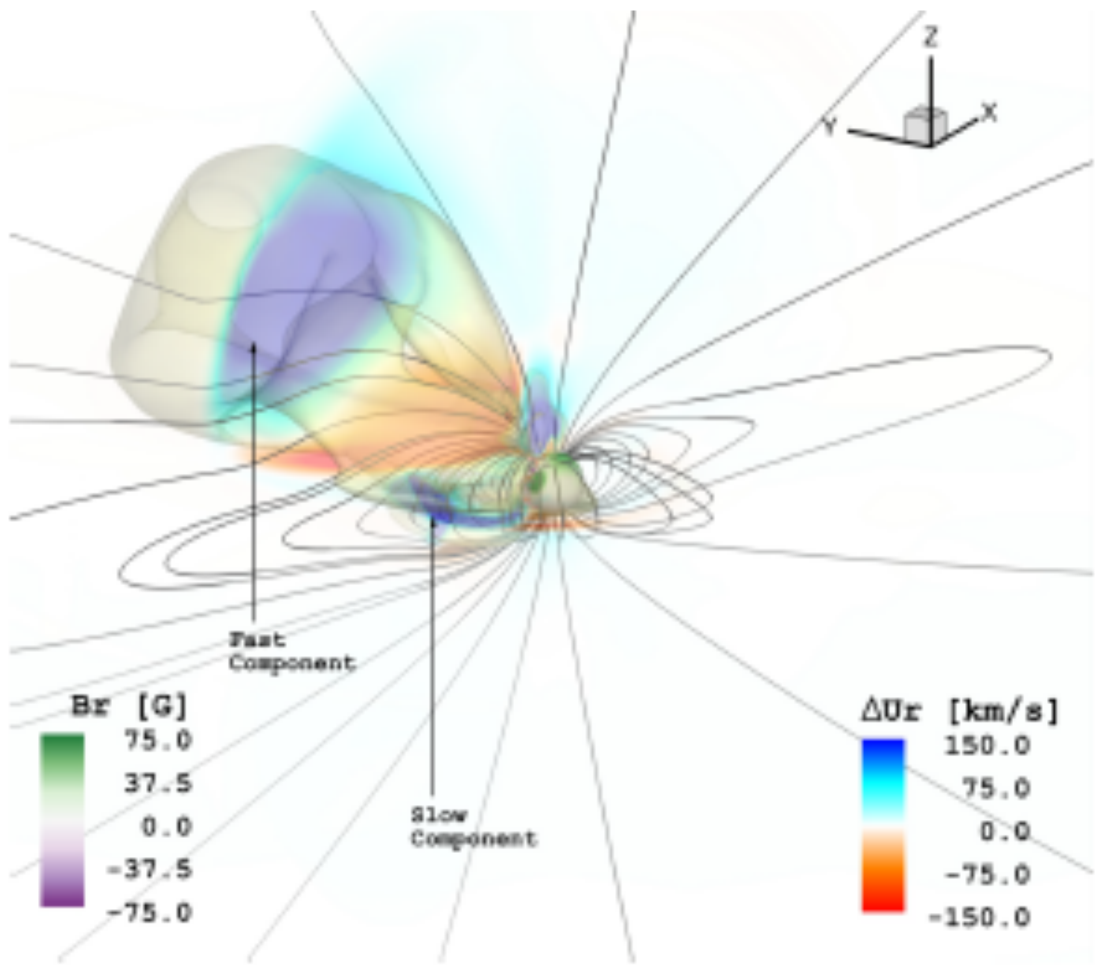
- space-borne VLBI system able to observe at frequencies above 200 GHz (1.5 mm wavelength) to at least 1 THz (300 μm wavelength) or even higher (extension down to 86 GHz considered)
- Trade-off between Space-Earth and Space-Space only baselines
  - Atmospheric frequency cut-off & larger baselines/better *uv* coverage, vs.
  - Greater sensitivity
- Space-space using receivers with system temperatures near the quantum limit and wide-band data acquisition systems, an acceptable baseline sensitivity can be achieved even with *moderate* size space-borne antennas.



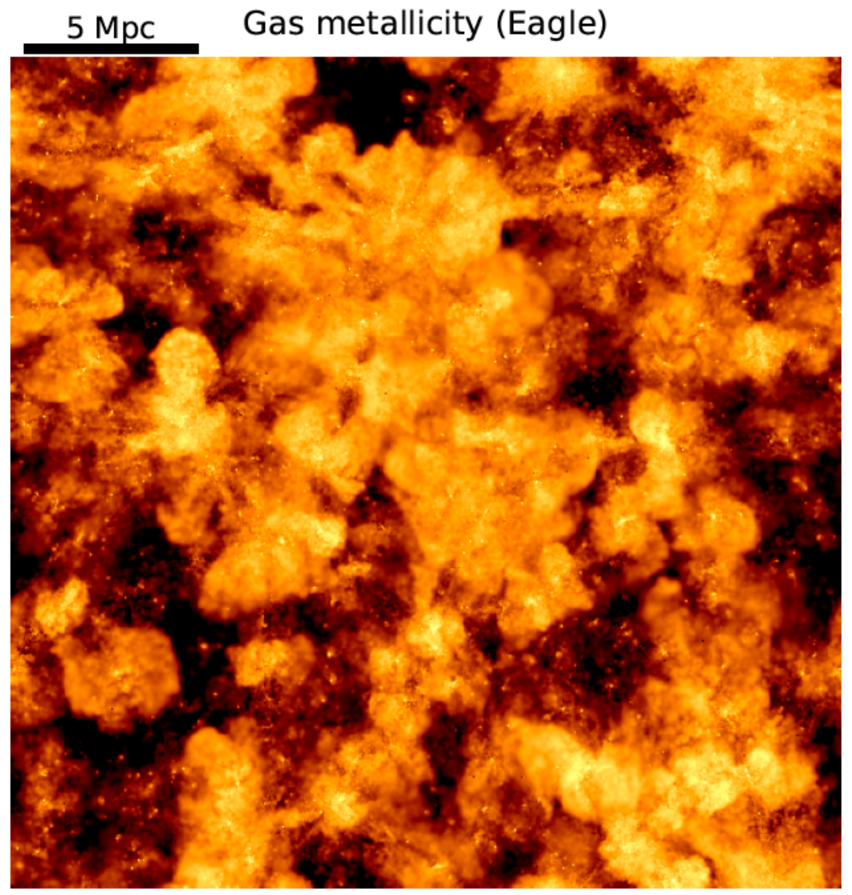
GRMHD model of Sgr A* image reconstructions with the EHI consisting of three satellites with short phase stability

The Voyage of Metals in the Universe from Cosmological to Planetary Scales — Nicastro & Kaastra et al.

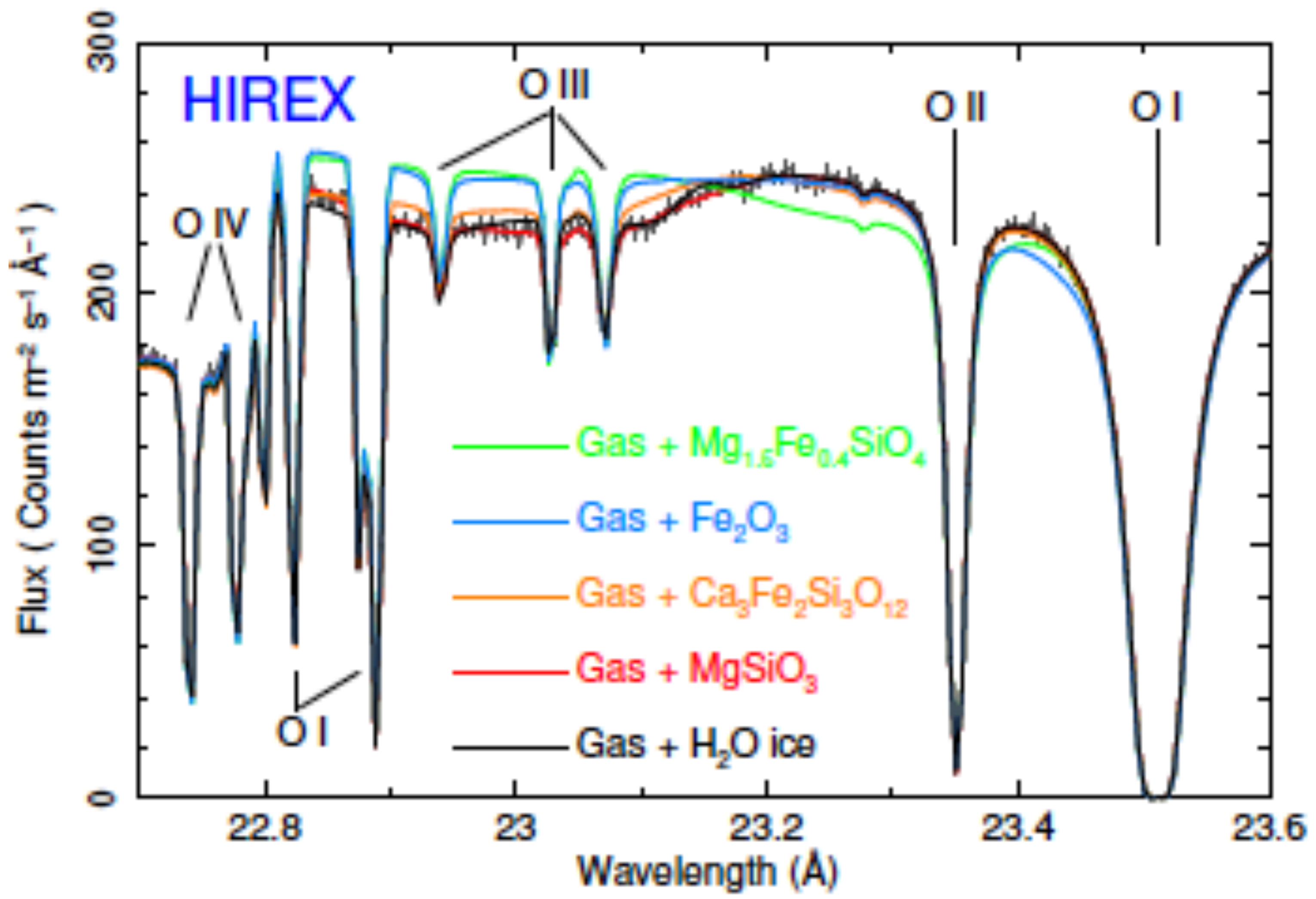
- Where and in what physical state are the Universe's missing baryons, and how does their wandering in-and-out of structures affect the evolution of the Universe and its different components?
- How do winds from AGNs, SNe and X-ray binaries redistribute metals in their surroundings?
- Where are the metals and in which atomic and solid states are they locked?
- How do stellar winds affect the chemical composition of exoplanets and the general conditions for the existence of life as we know it?



Doppler shifts in a coronal mass ejection



WHIM



Gas versus dust states

HiReX

Medium-class soft X-ray (0.2-1.5 keV) dispersive spectrometer
resolving power: 5000–10000
effective area: 1500–2000cm2

- Si-pore optics
- gratings
- CCD-type detectors

Parameters @ 0.5 keV

Mission	Instrument	$A_{\rm eff}$ (cm^2)	R	FoM
HiReX		1 500	10 000	$\equiv 1$
Chandra	*LETGS*	12	500	0.02
XMM-Newton	*RGS*	90	400	0.05
XRISM	*Resolve*	125	100	0.03
Athena	*X-IFU*	5 900	200	0.28

FoM = S/N ~ $\sqrt{(A_{\rm eff}R)}$ for weak lines (statistics limited)