Brief Introduction to China's Space Astronomy Programs

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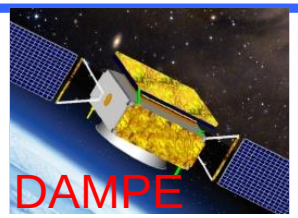
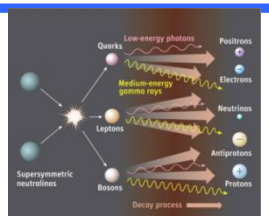
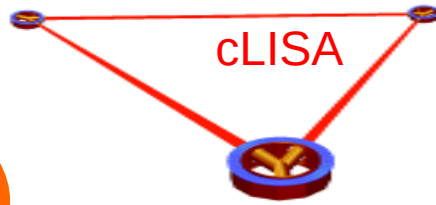
China's Space Astronomy Satellites

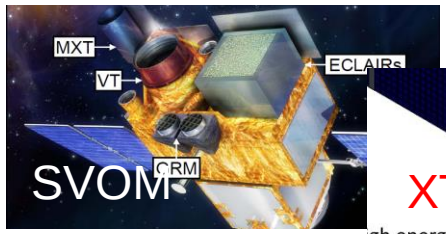


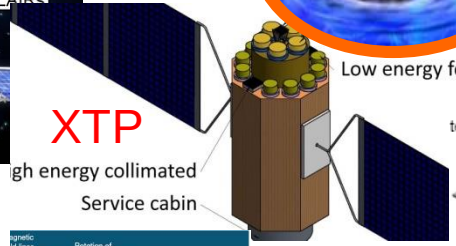


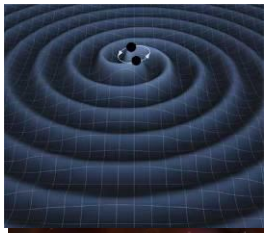


e/CR /GRW

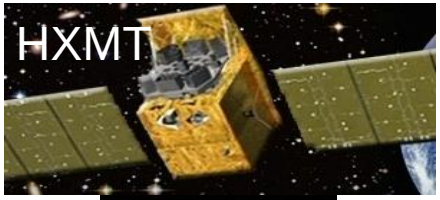
γ-ray

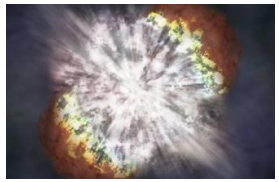


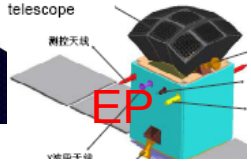


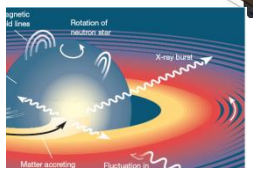


X-ray

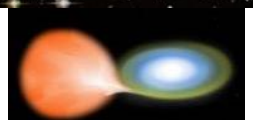


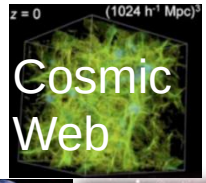




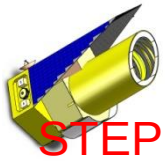


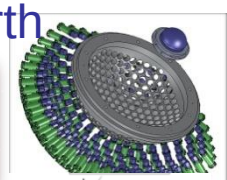
UV



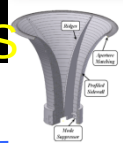


IR/O





radio



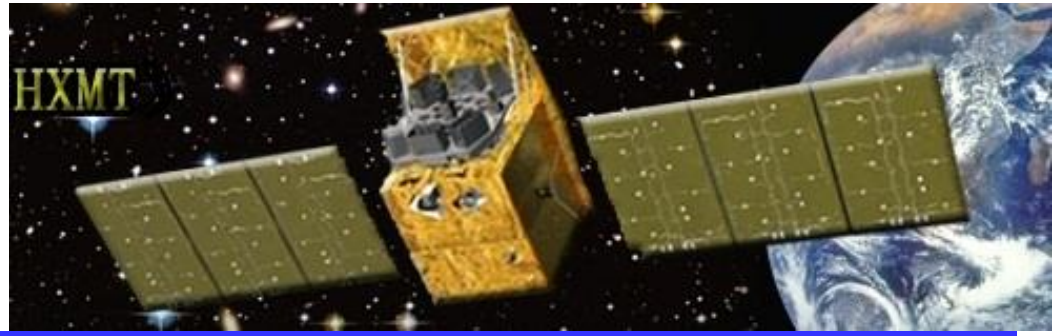
2015 2020 2025 2030

Hard X-ray Modulation Telescope (HXMT)

- Main scientific objectives (1-250 keV energy band)
  - ✓Scan monitoring of the Galactic plane → transients watch dog: need ground follow-up observations.
  - ✓Pointed observations → Black hole and neutron star x-ray binaries: need coordinated ground observations

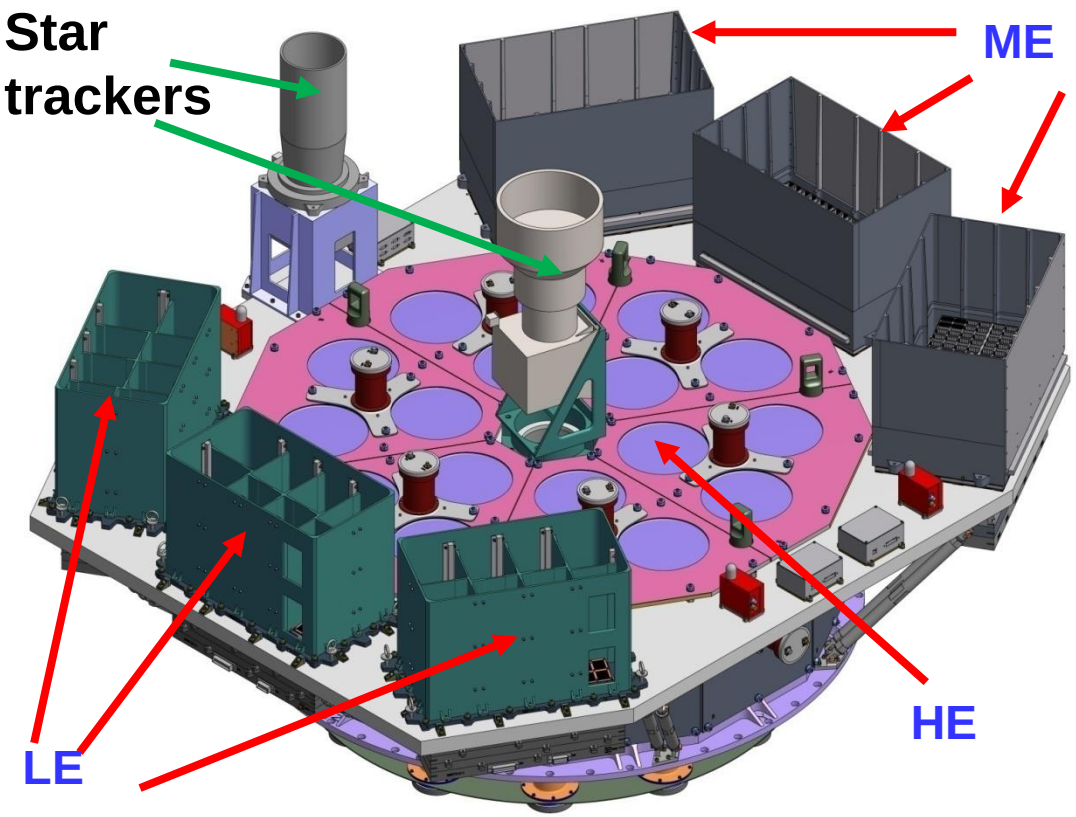
Satellite Facts:

- ✓ Mass: ~2800 kg
- ✓ Orbit: 550 km, 43°
- ✓ Lifetime: 4 yrs



Officially approved in March 2011
Now in final stages of FM and calibration
Planned launch time: Aug. 2016
Core programs open to many international scientists and organizations to reward their contributions to HXMT

HXMT Payloads



High Energg (HE):

NaI/CsI, 20-250 keV, 5000 cm^2

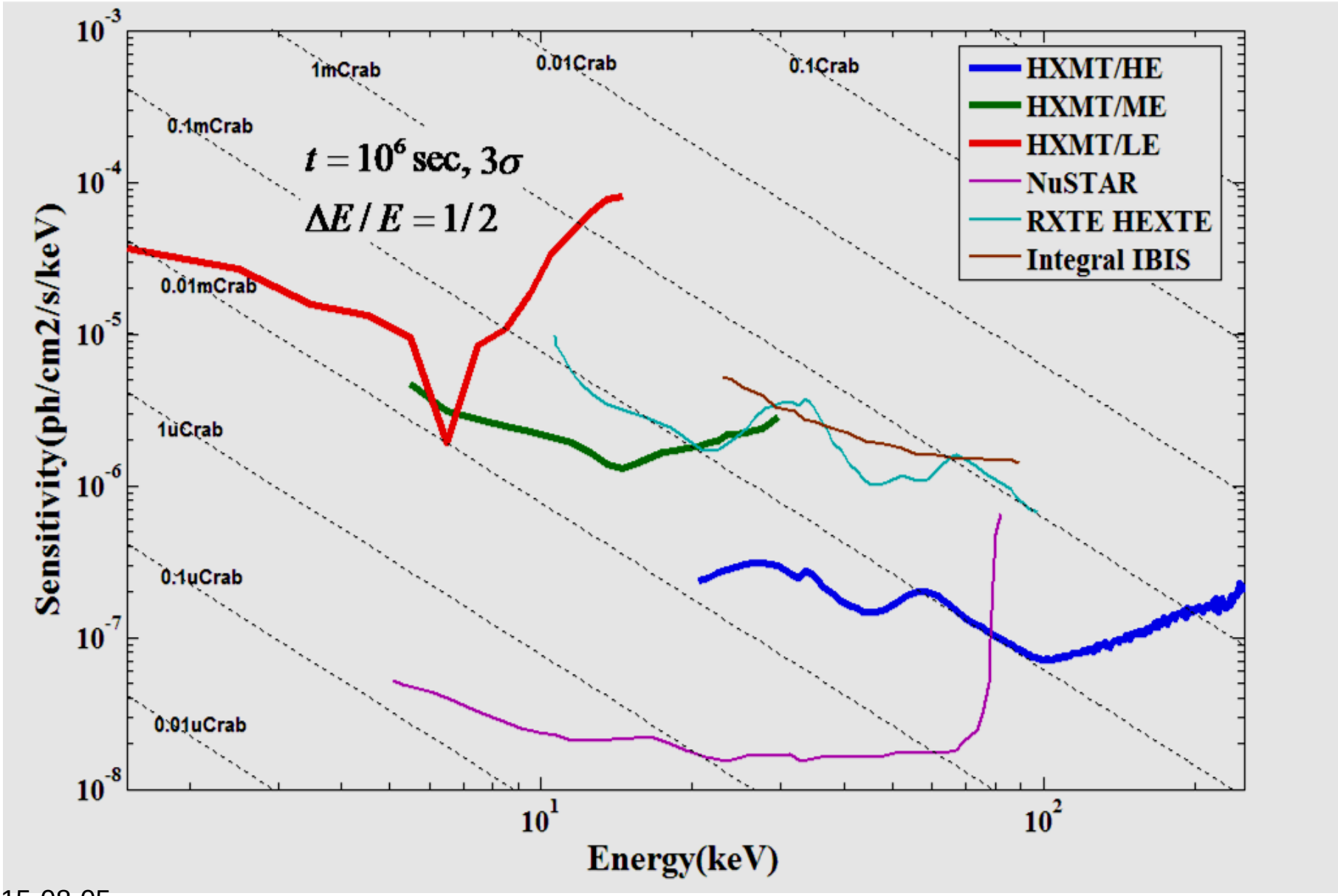
Medium (ME):

Si-PIN,5-30 keV, 952 cm^2

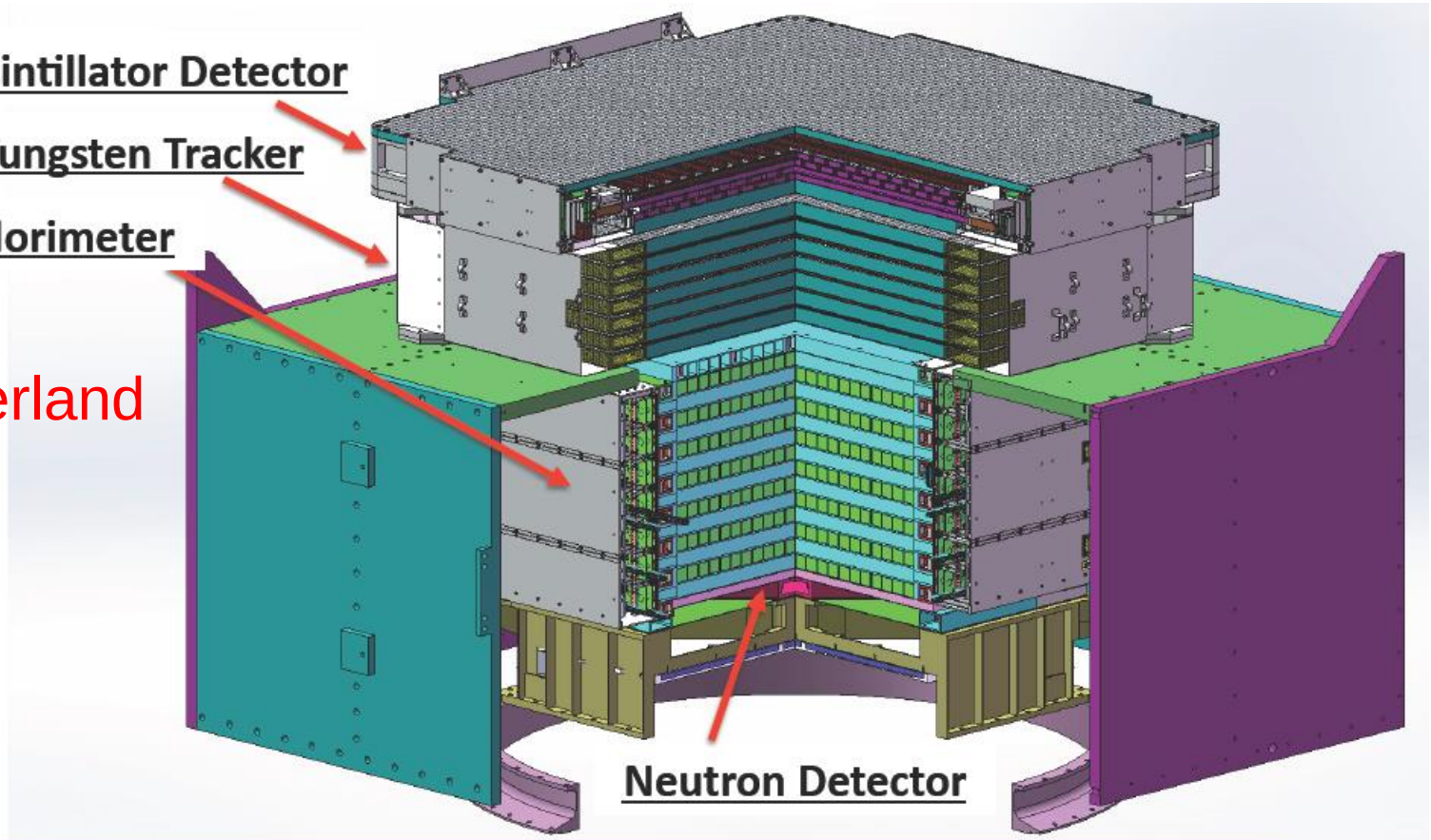
Low Energy (LE):

SCD,1-15 keV, 384 cm^2

HXMT Sensitivity



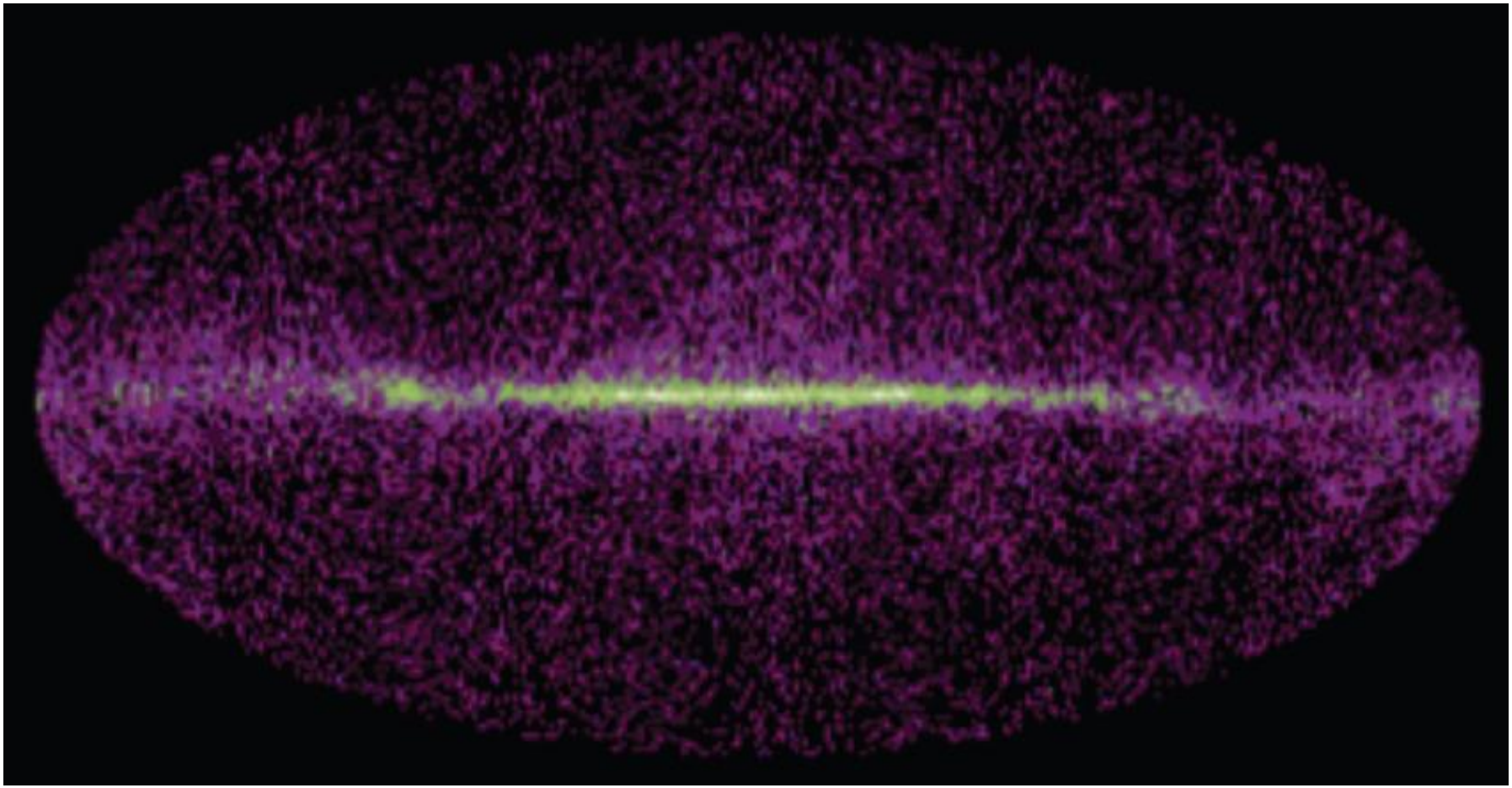
DAMPE: launch in ~Dec. 2015



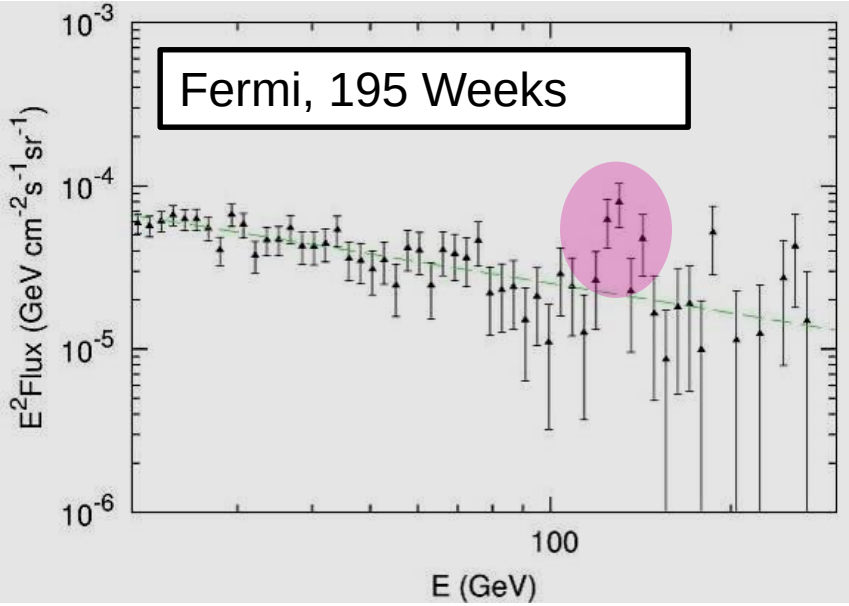
+ Switzerland
+ Italy

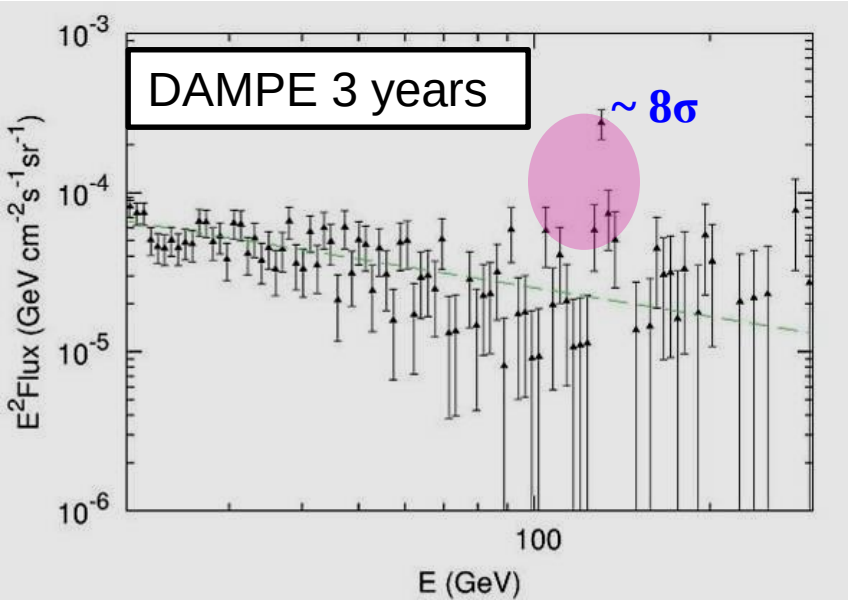
W converter + thick calorimeter (total 33 X_0)
+ precise tracking + charge measurement ➡
high energy γ-ray, electron and CR telescope

Gamma-ray mapping by 30 days



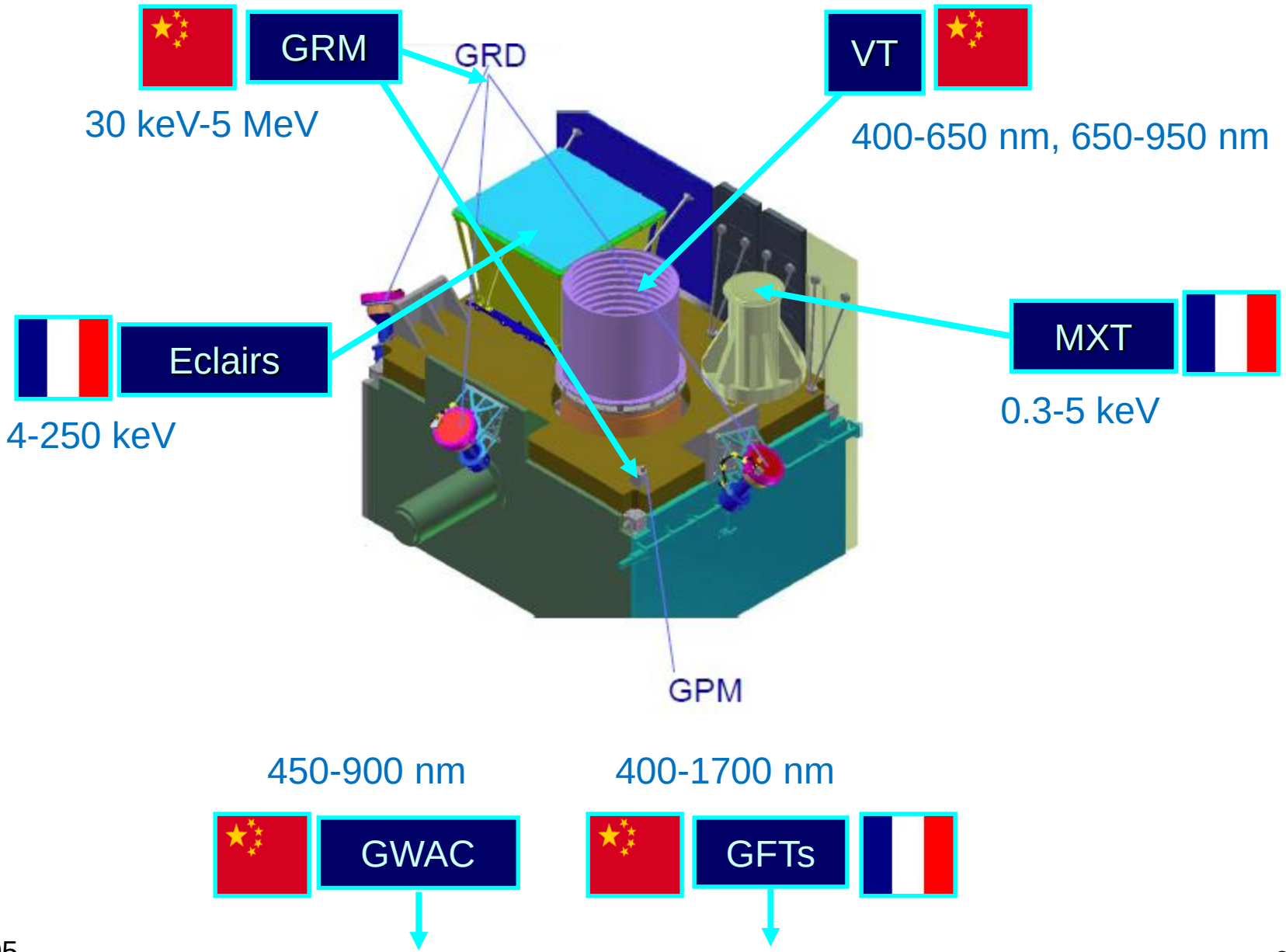
DAMPE for gamma-ray line observations



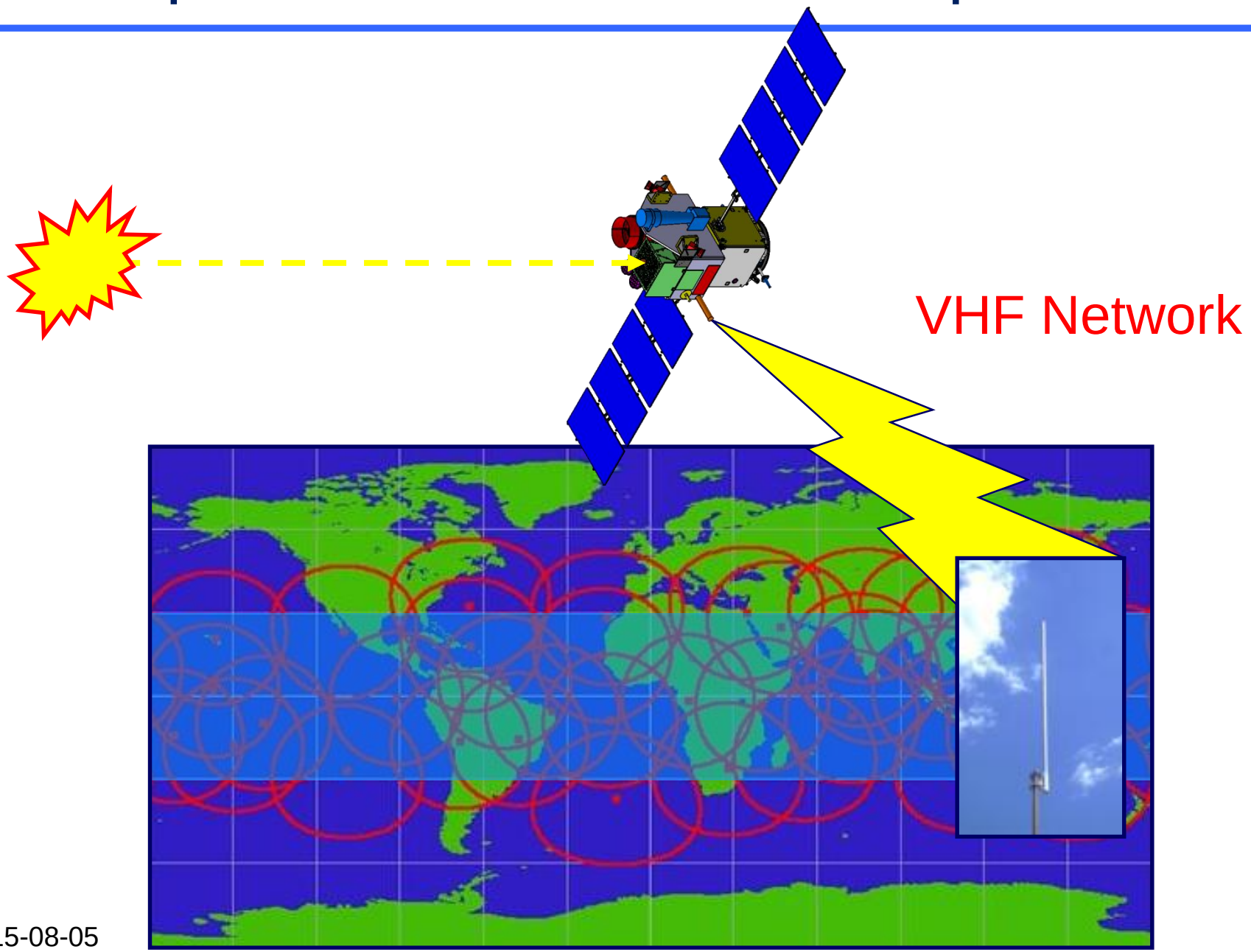


DAMPE will confirm or deny the “suspicious” dark matter annihilation line of Fermi with high significance

SVOM: ~2021 launch (China-France)



Prompt dissemination of GRB parameters



GRB observation strategy

Space

GRB trigger provided by ECLAIRs at time T_0

T_0 + 5 min

VT (V & R band photometry)
MXT (Soft X-ray photometry)

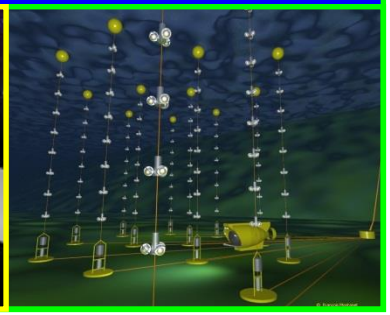
Ground

T_0 +1 min

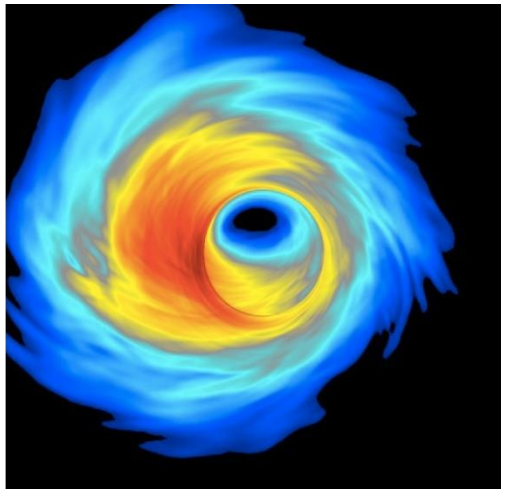
GWAC
GFTs (g, r, i, J, H)

1-2 m robotic telescopes

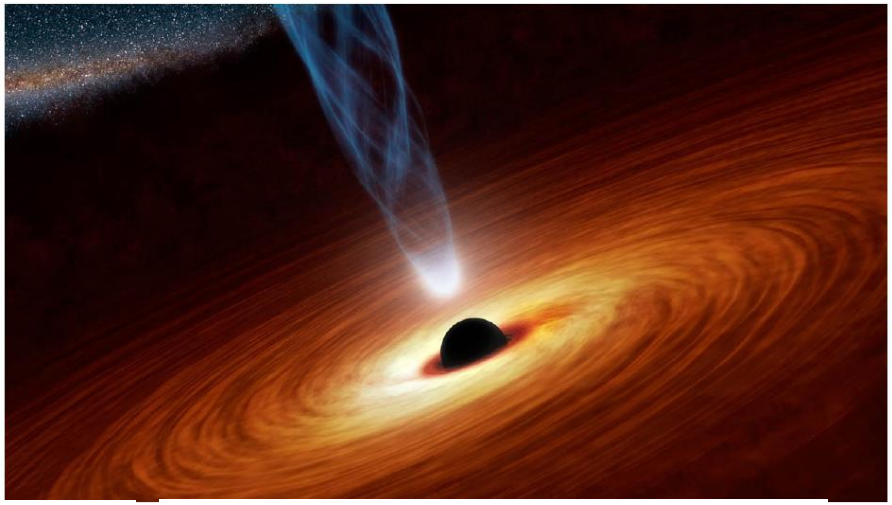
Multi messenger follow-up

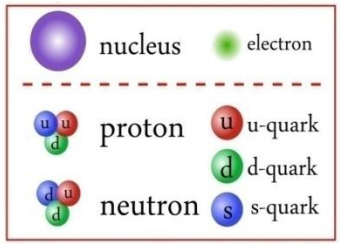


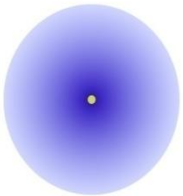
X-ray Timing and Polarization (XTP) mission



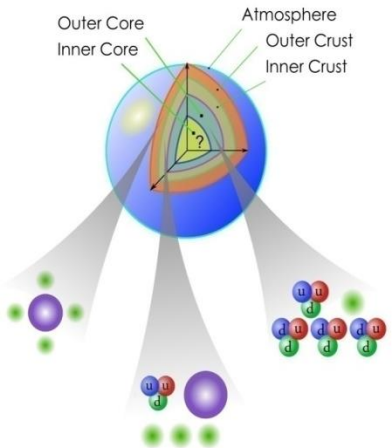
Singularity?
Neutron or
Quark Star?
Extreme gravity
magnetism
density



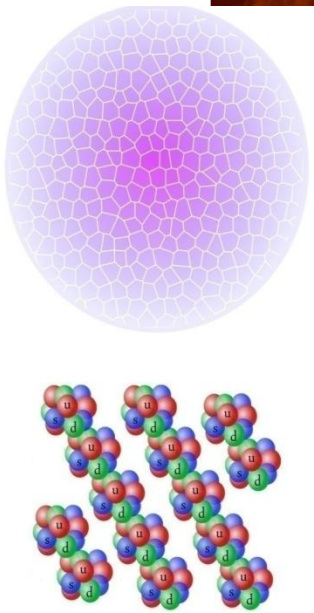




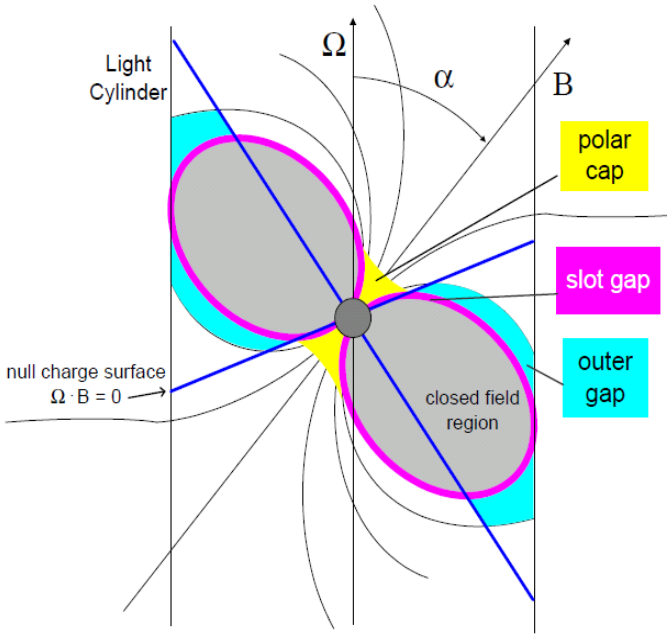
Landau's Gigantic Nucleus



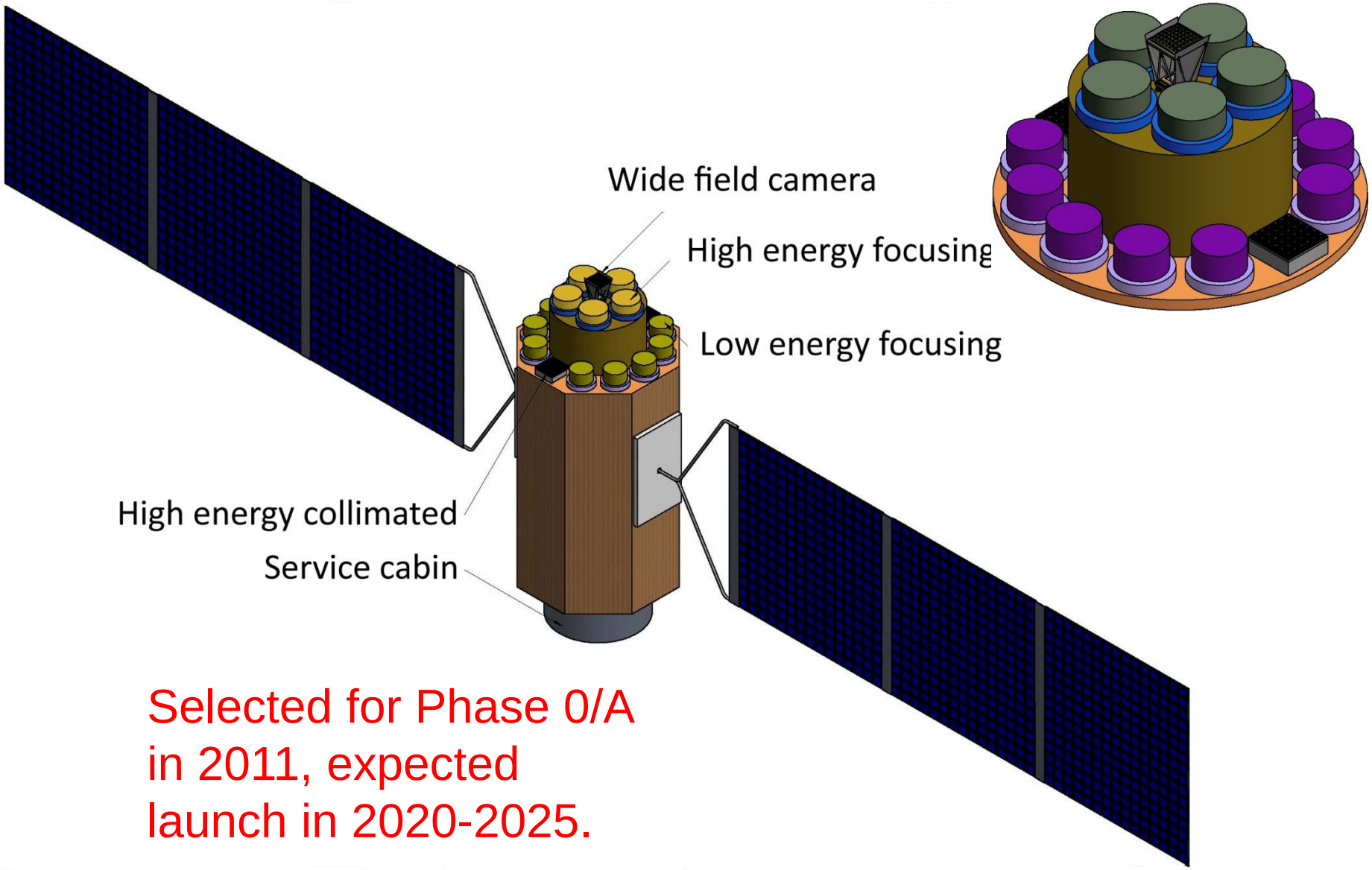
Normal Neutron Star



Quark Clustering Star



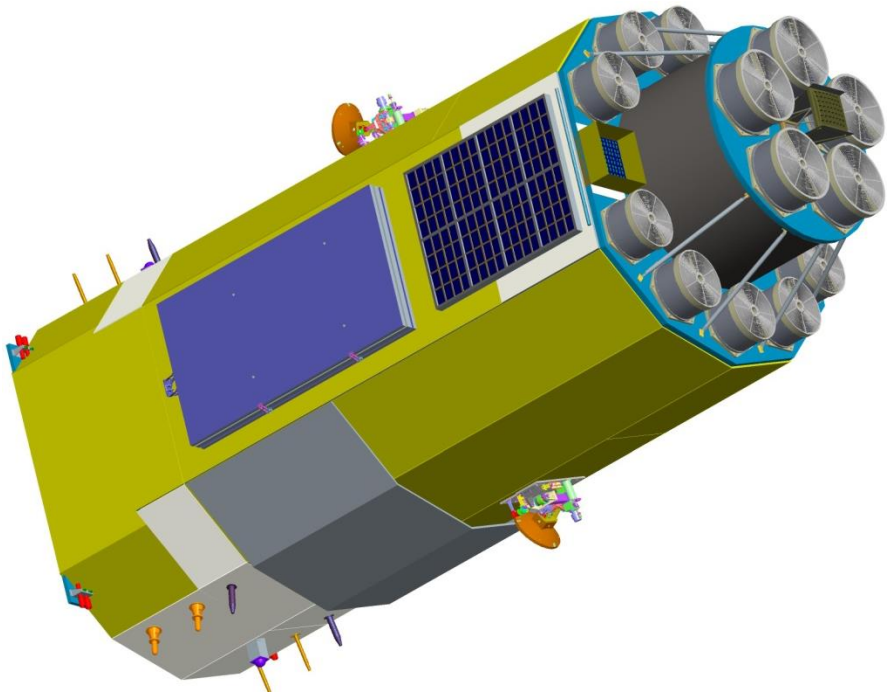
XTP satellite baseline design

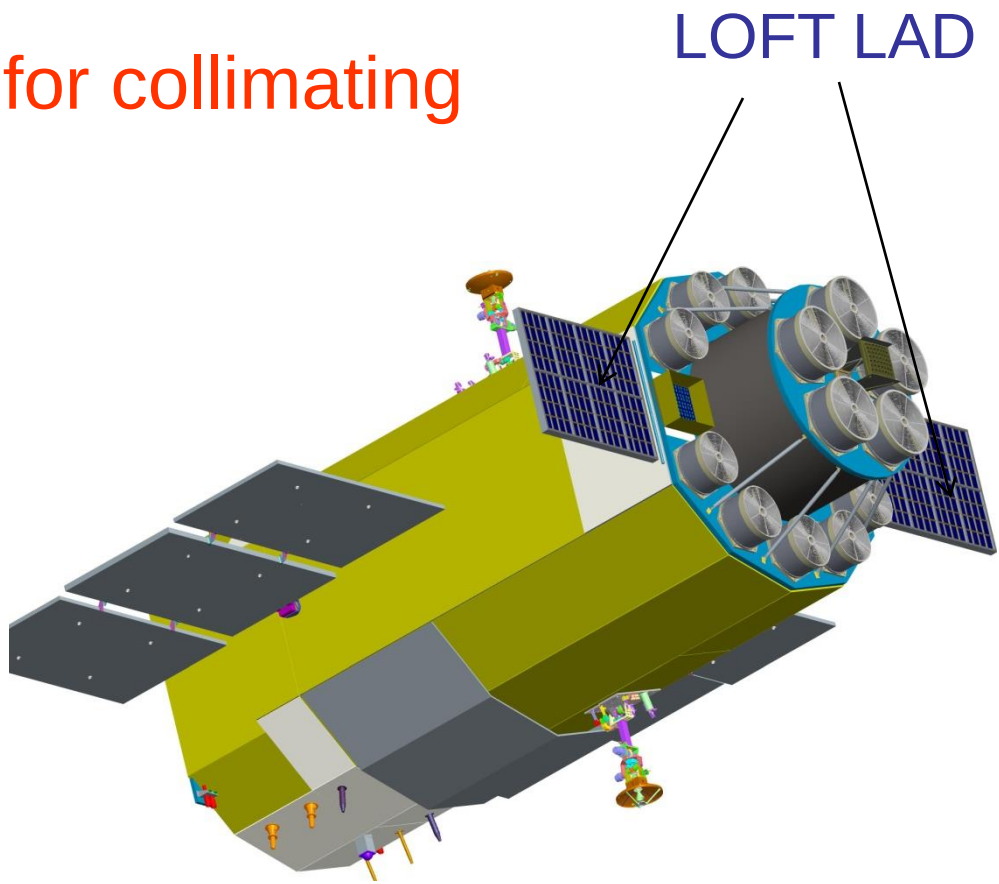


Selected for Phase 0/A in 2011, expected launch in 2020-2025.

Enhanced XTP (or eXTP): option 1

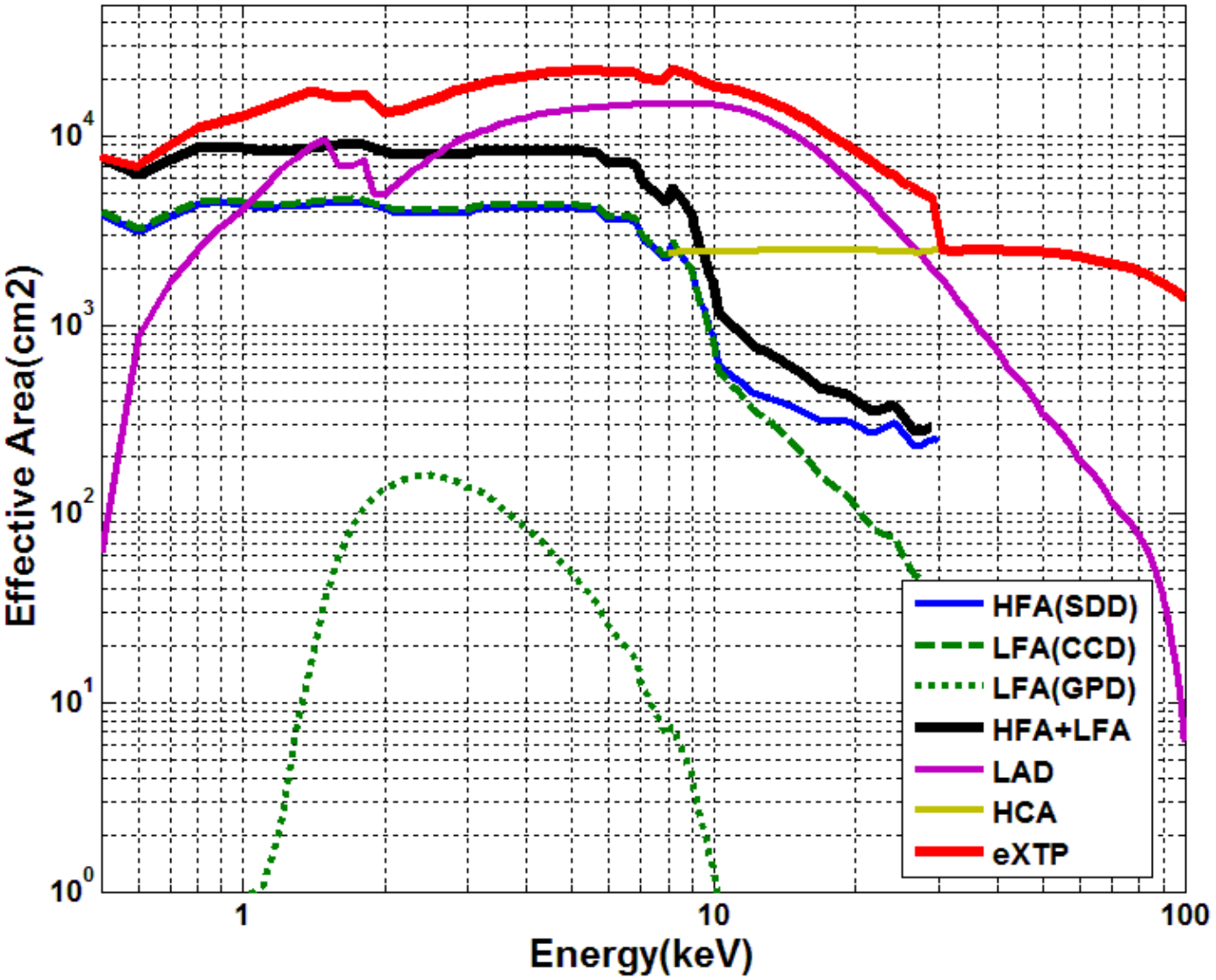
- 2 lines*5 columns*2 panels = 20 LAD
  - ~1.5 m^2 effective area for collimating detectors





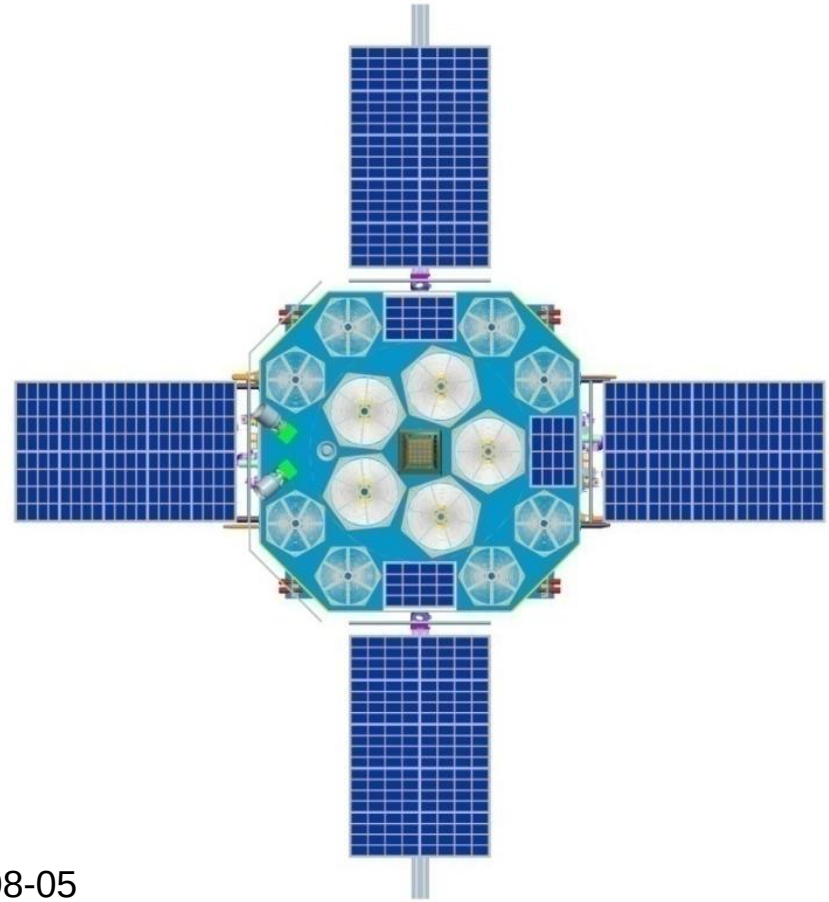
+ LOFT consortium: Italy, UK, Germany, Switzerland, Netherland …

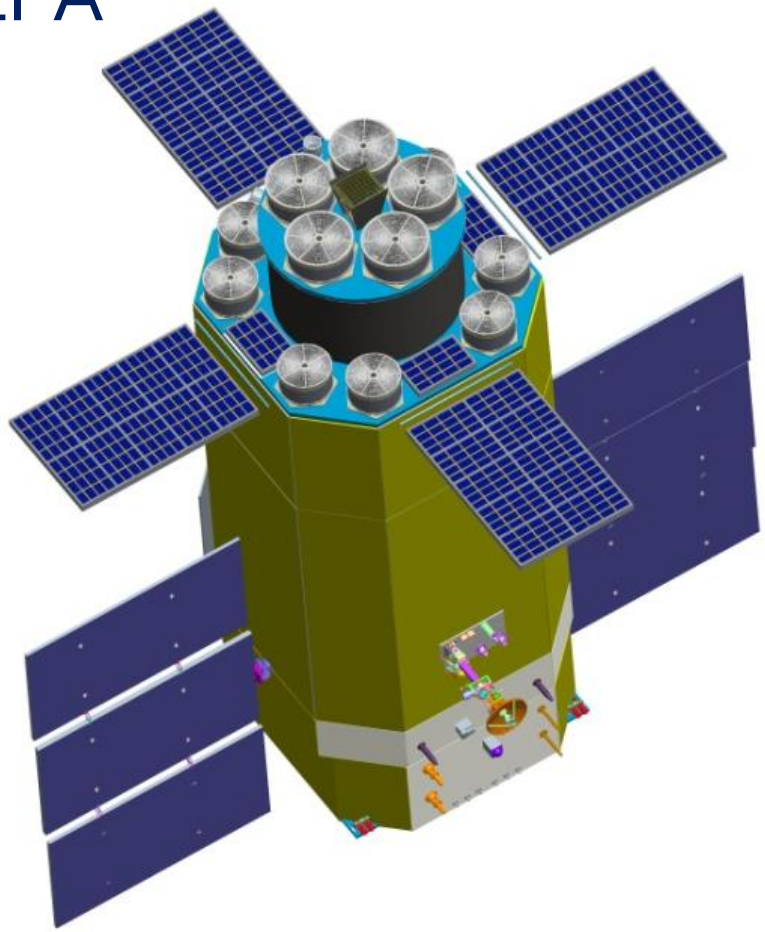
Effective area of eXTP option 1

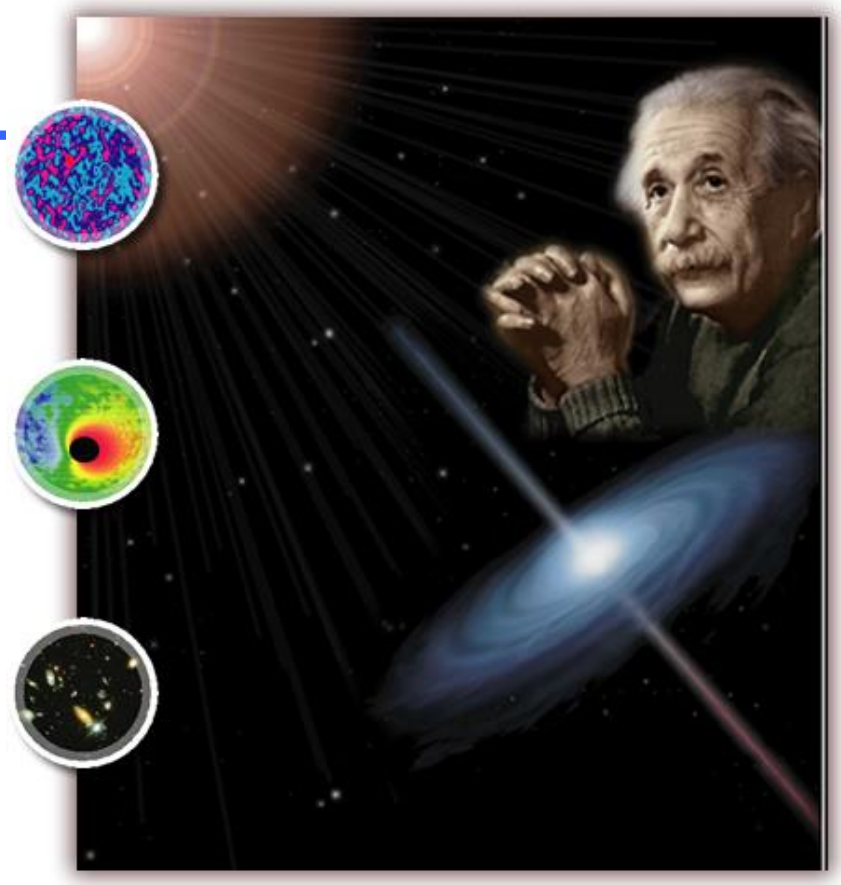


Enhanced XTP (or eXTP): option 2

- 2 lines*5 columns*4 panels+2 = 42 LAD
  - ~3 m^2 effective area for collimating detectors
  - Loss of ~ 0.1 m^2 of XTP LFA

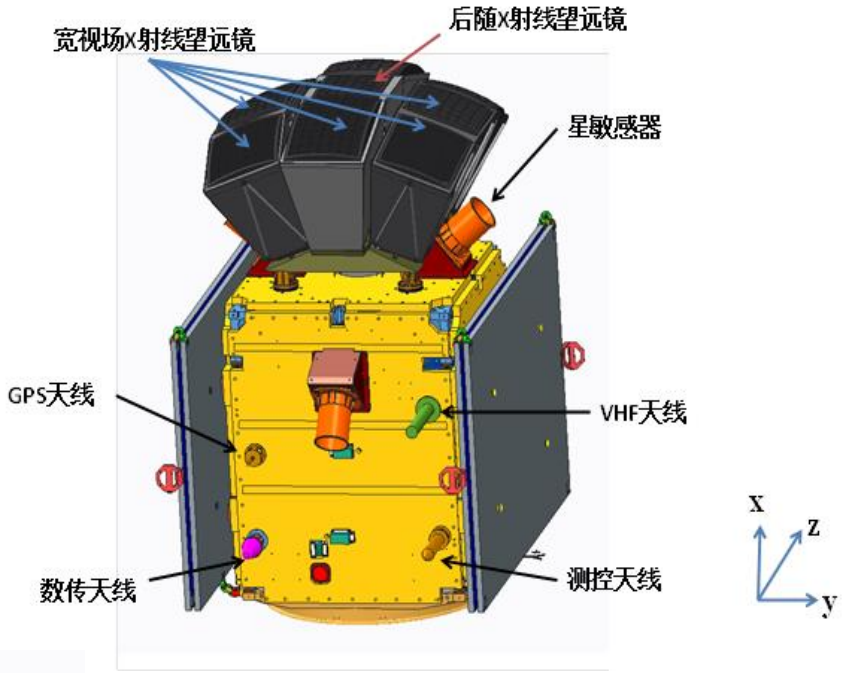


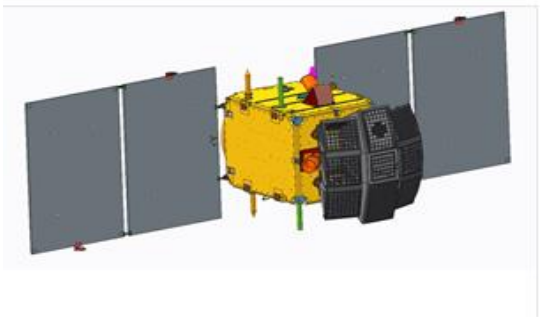


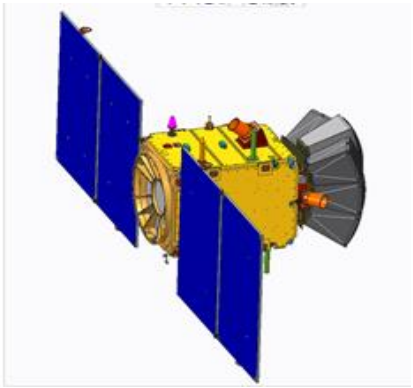


Einstein Probe (EP)

Lobster-eye optics

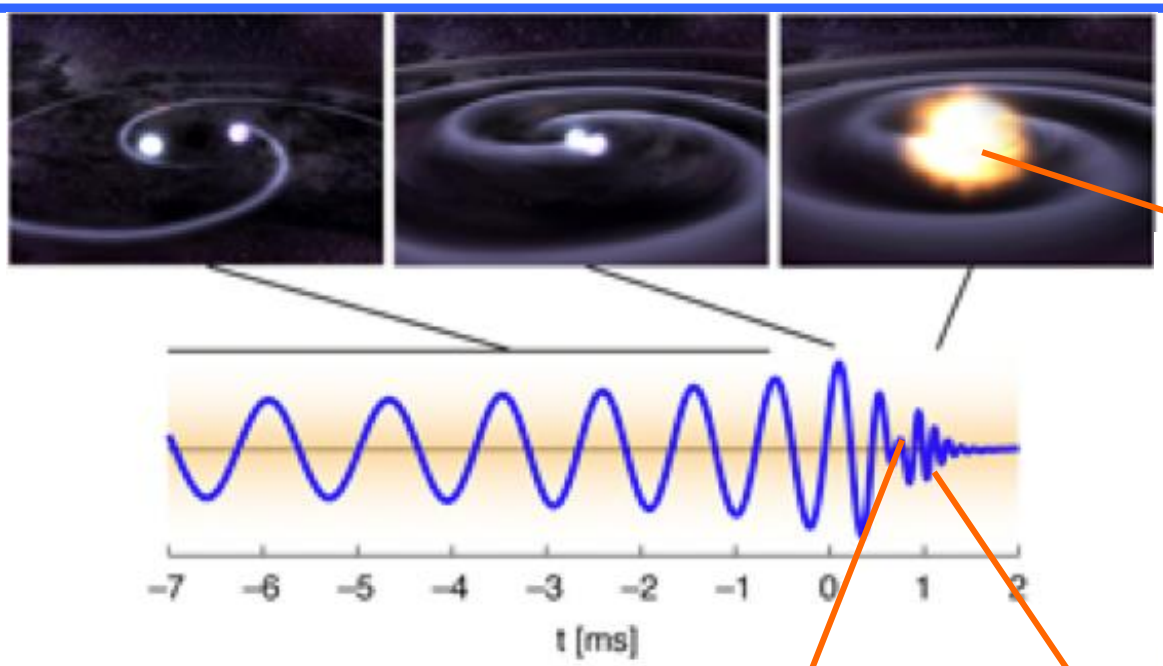


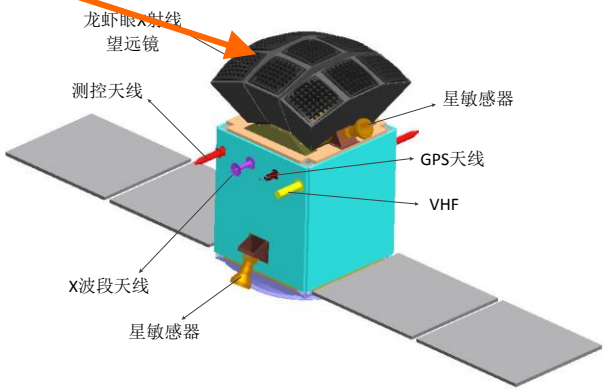




Selected for Phase 0/A in 2013, proposed for launch in 2020-2025.
+ UK

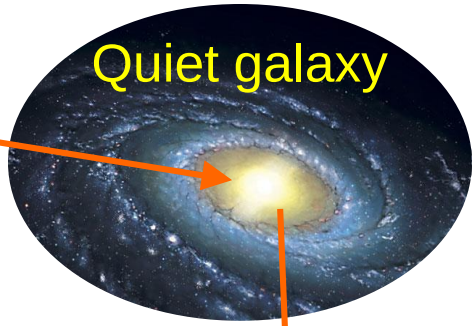
EM counterparts of GW explosions

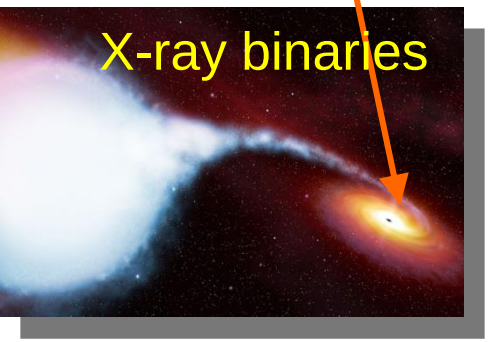


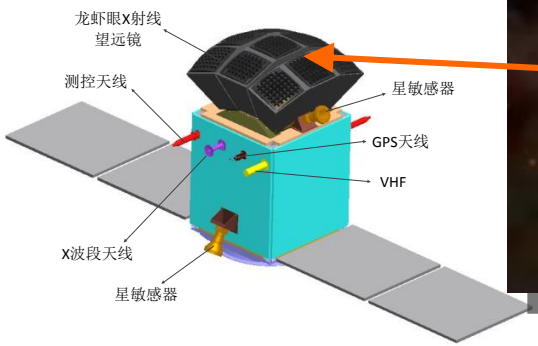


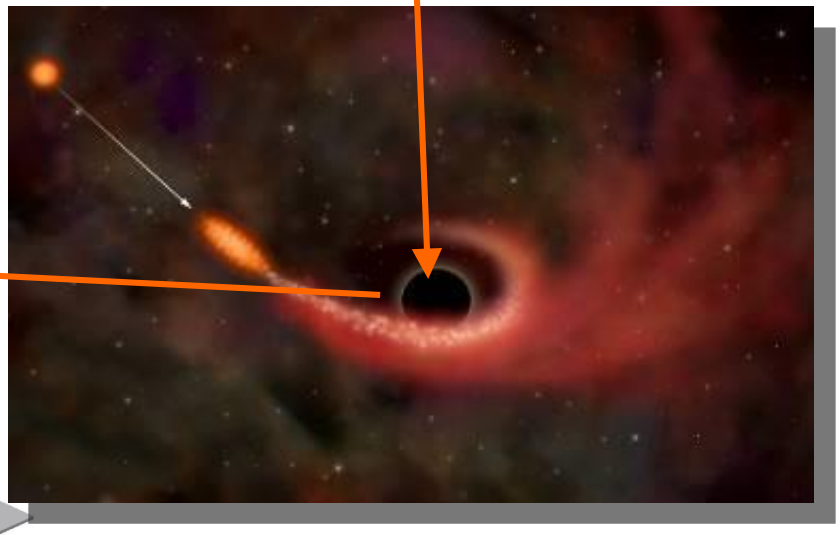
~2018

Black holes of all scales in the universe

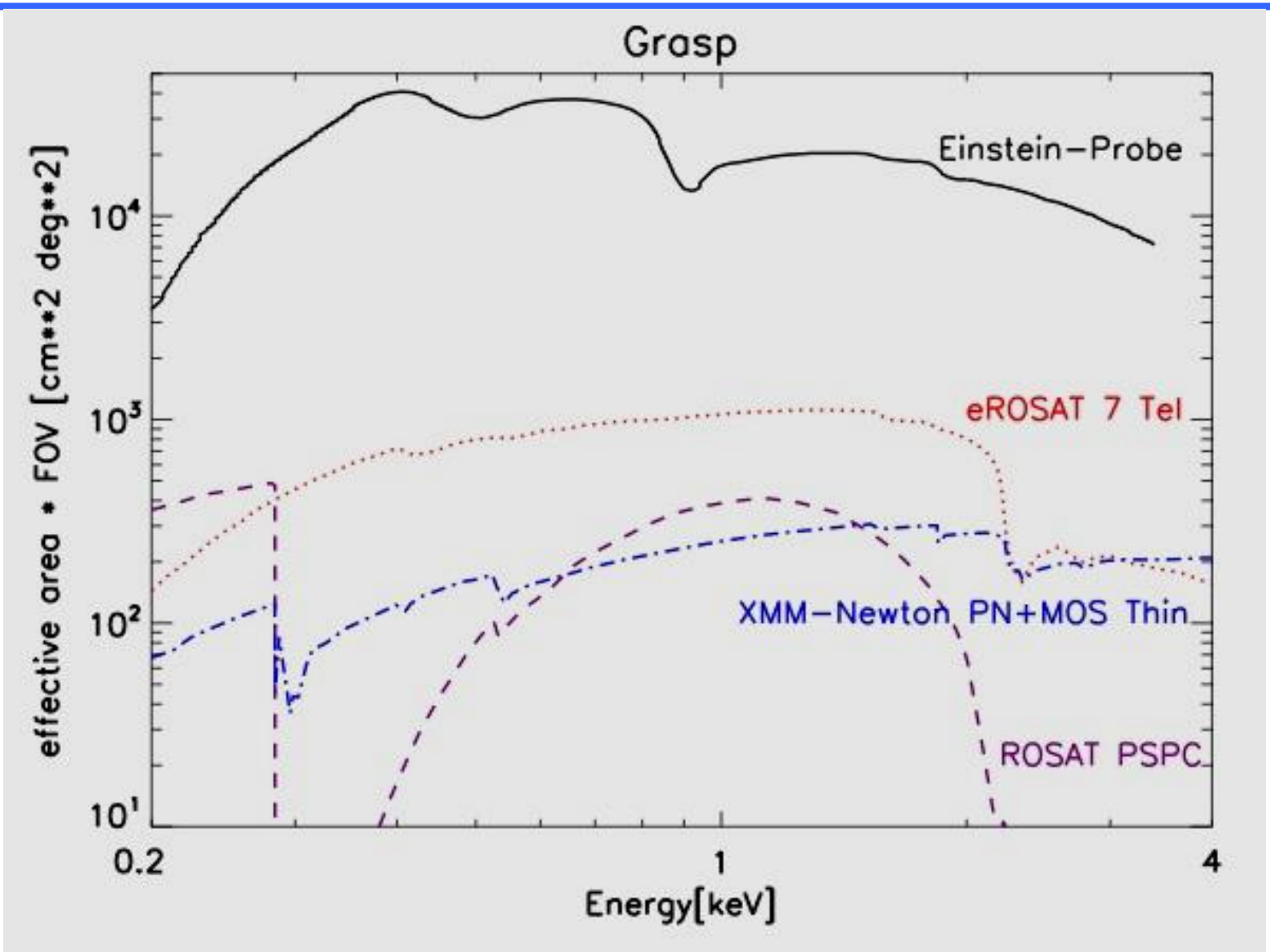








Capability of Einstein Probe



China's Space Station Program

2020

Phase -II

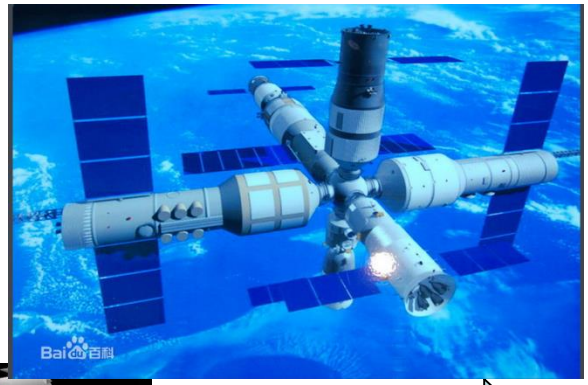
2016

Phase -II

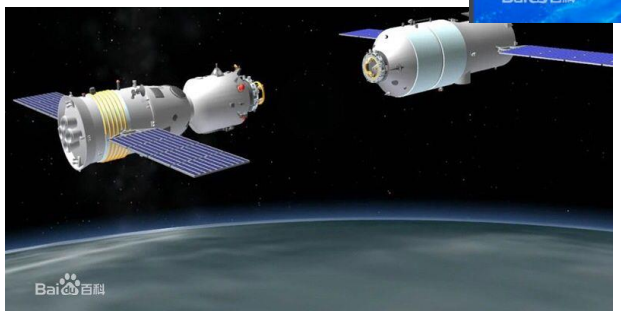
2011

Phase -I

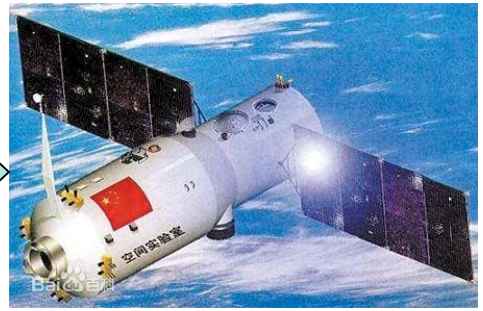
2003



Space Station
3 large modules
+ 2 m telescope
~10-year lifetime



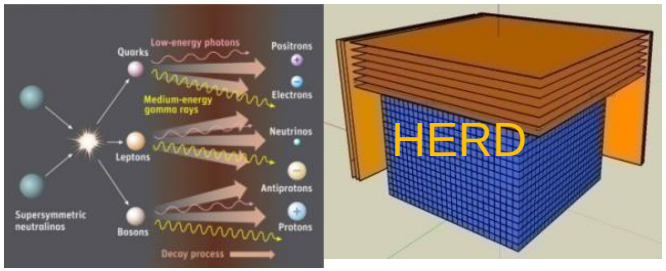
Space lab:
no living cabin



10 astronauts in 5 flights → space walk

China's Space Station Astronomy Program

e/CR

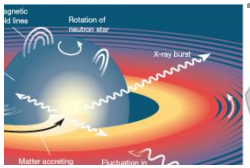


γ-ray

NEATER

(a mini XTP but with low-E pol.)

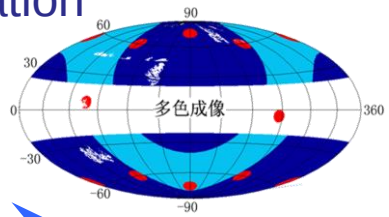
X-ray



ASM

?

Chinese Space Station Optical Survey Dark Energy



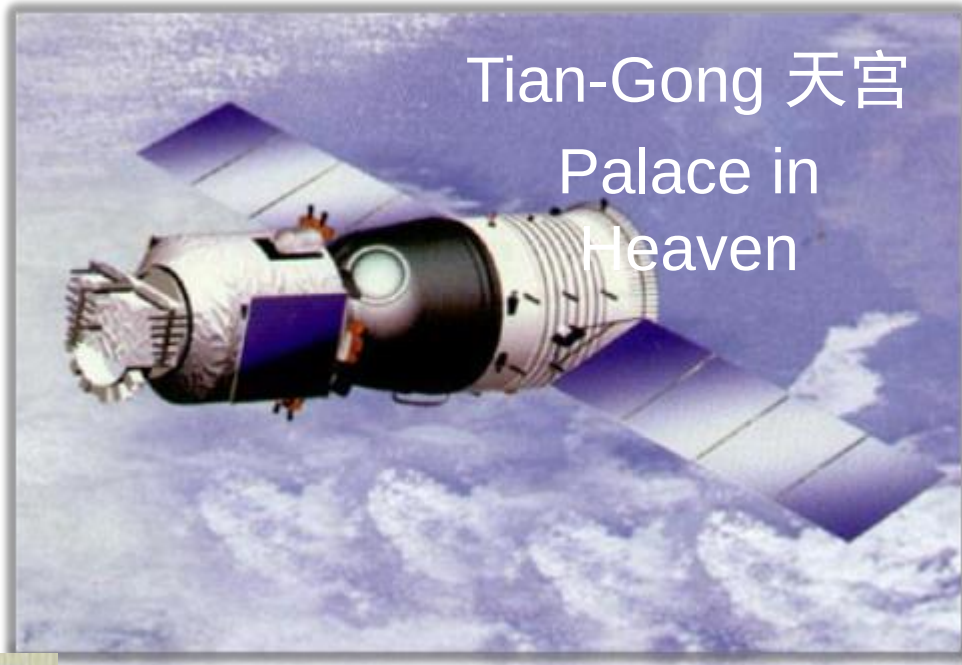
(EP in scanning mode without XFT)

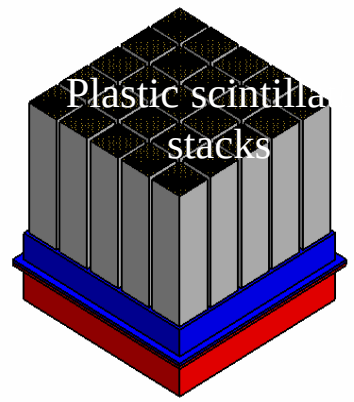
IR/O

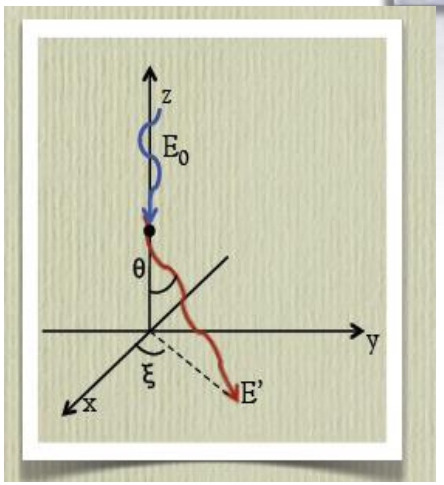
2015 2020 2025 2030

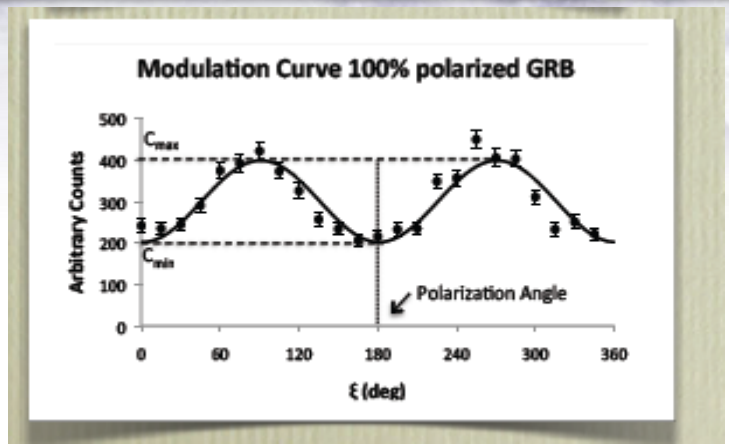
Gamma-ray burst polarization : POLAR

- China- Switzerland collaboration
  - Energy range: 50-350 keV; FOV of POLAR: ~½ sky
- Onboard China's spacelab TG-2: launch time Aug. 2016
- Main science: GRB jet & central engine; tests of quantum gravity theories

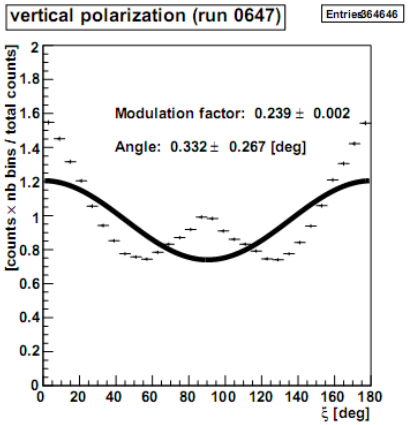


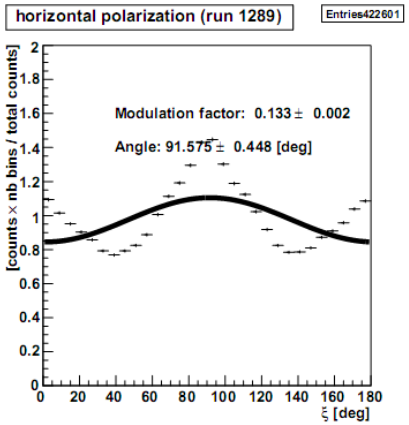


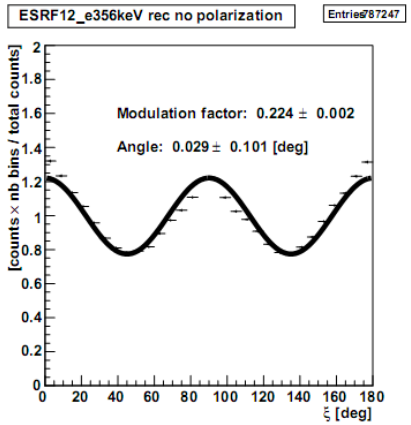


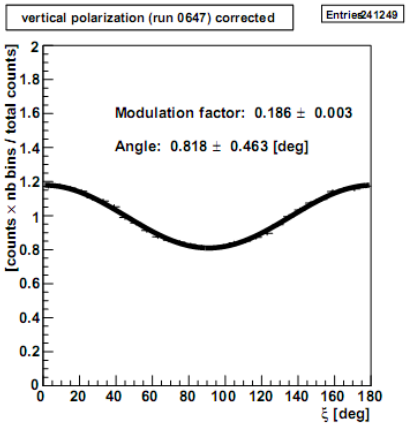


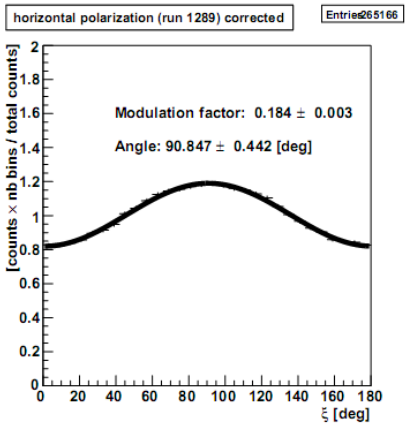
POLAR ESRF Calibration







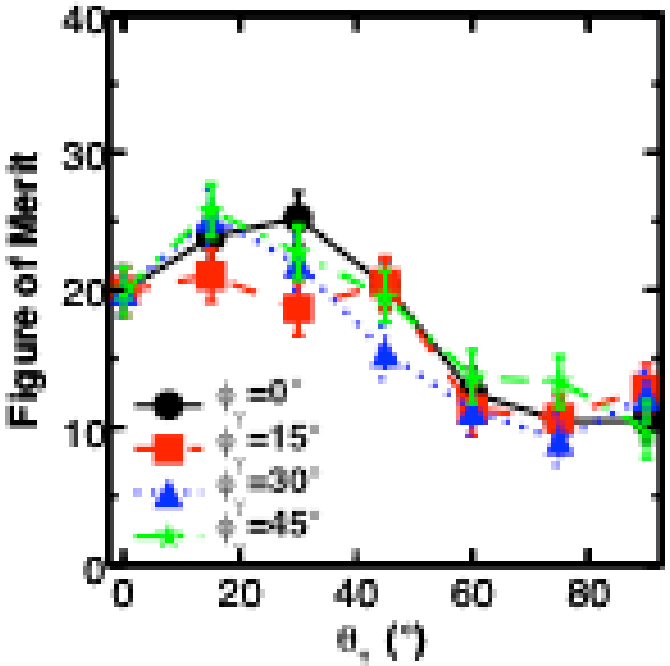


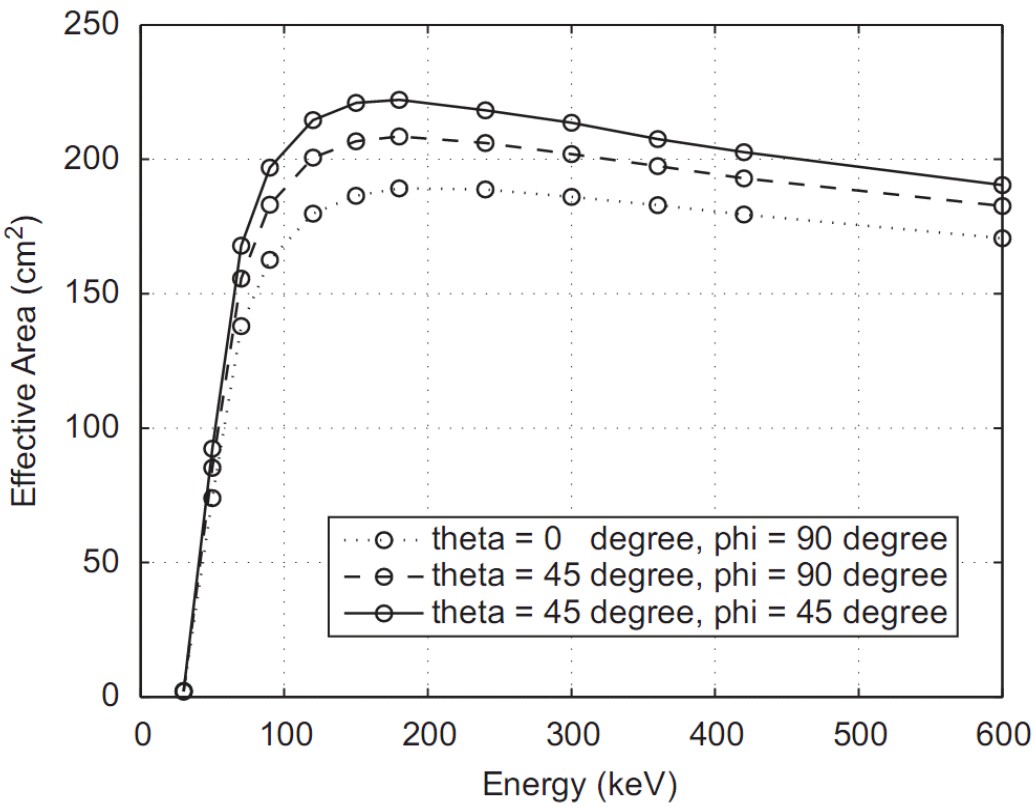


Results agree with Monte-Carlo simulations

Effective Area of POLAR

- Monte Carlo based study
- A_{eff} is dependent on E and incoming photon angle
- Figure of merit: A_{eff} x μ_{100}





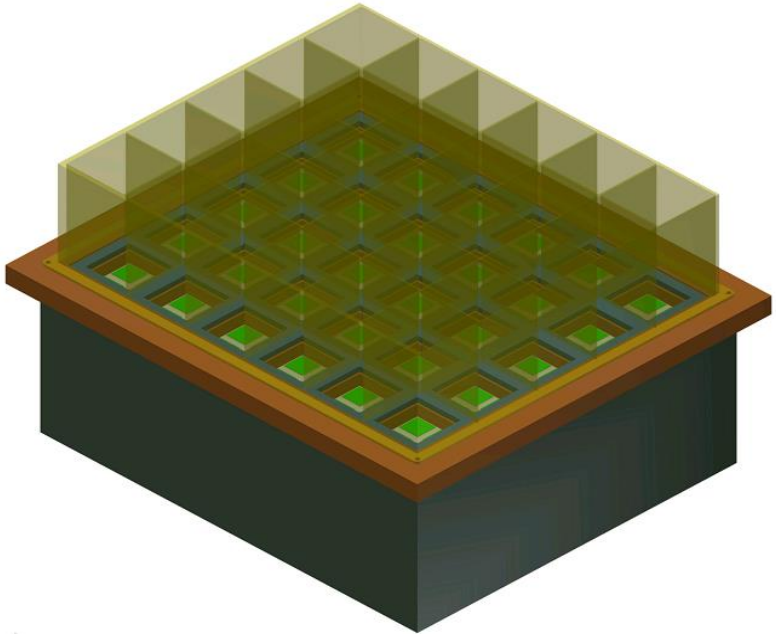
S. Xiong, N. Produit, B. Wu, Expected performance of a hard X-ray polarimeter (POLAR) by Monte Carlo simulation, Nucl. Instr. and Meth. A 606 (2009) 552

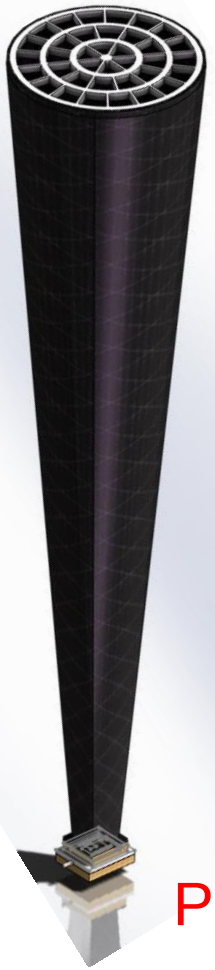
E. Suarez Garcia, Ph.D. Thesis, Univ. de Genève, 2010

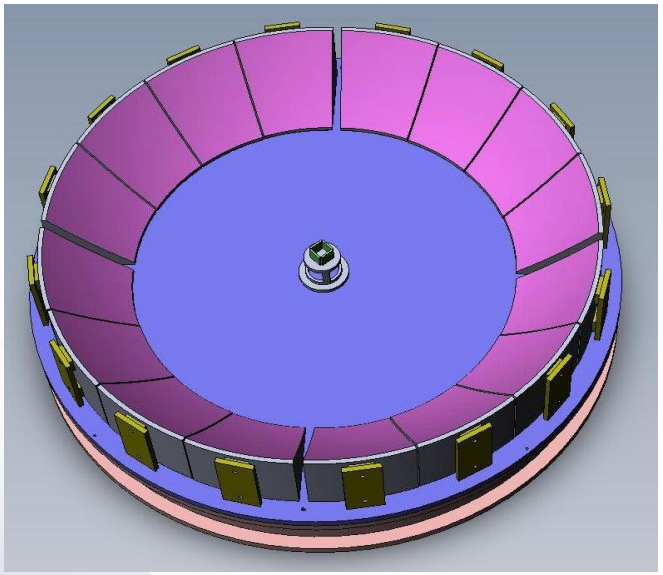
NEATER Payloads: 2020 launch

+ Italy

F~ 1 m Single ref.
MPO or nested shells?





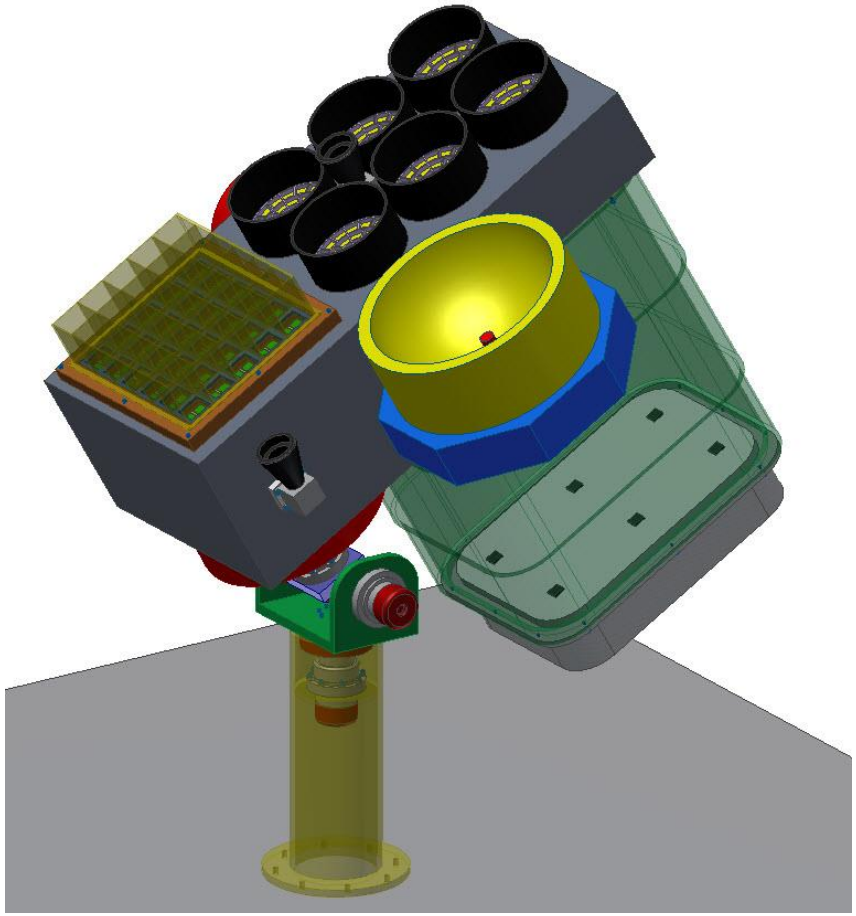


Polarization
E=0.25 keV
~1200 cm^2

Collimated detectors
Si ~400 cm^2

Energy: Si ~100 cm^2
Polarimetry: GPD 50 cm^2

Payload Assembly

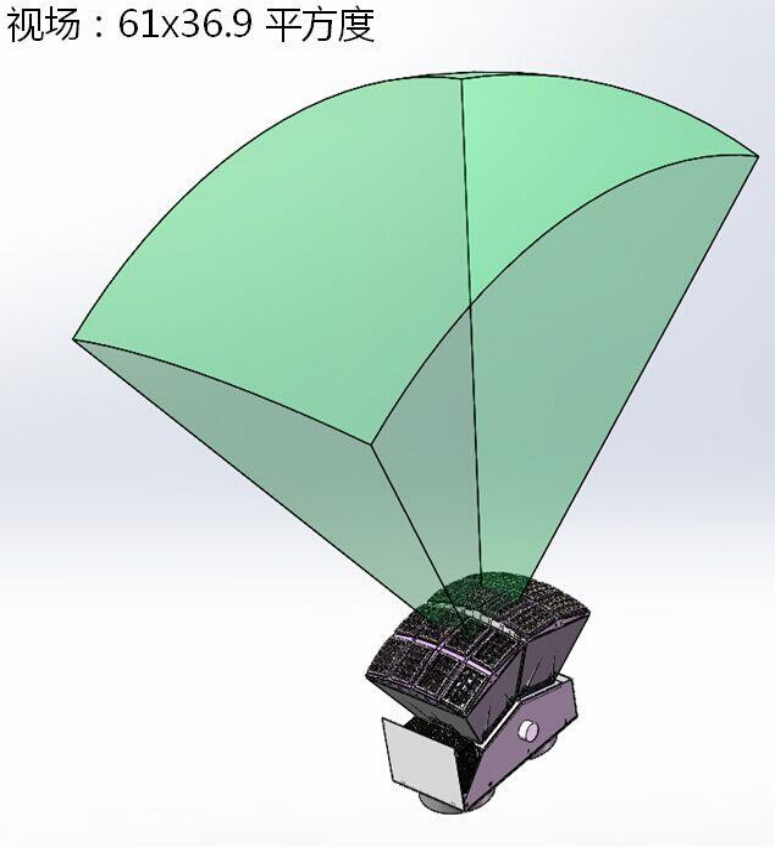


Weight：146 kg
Power：250 W
Size
<1500*1400*1500mm

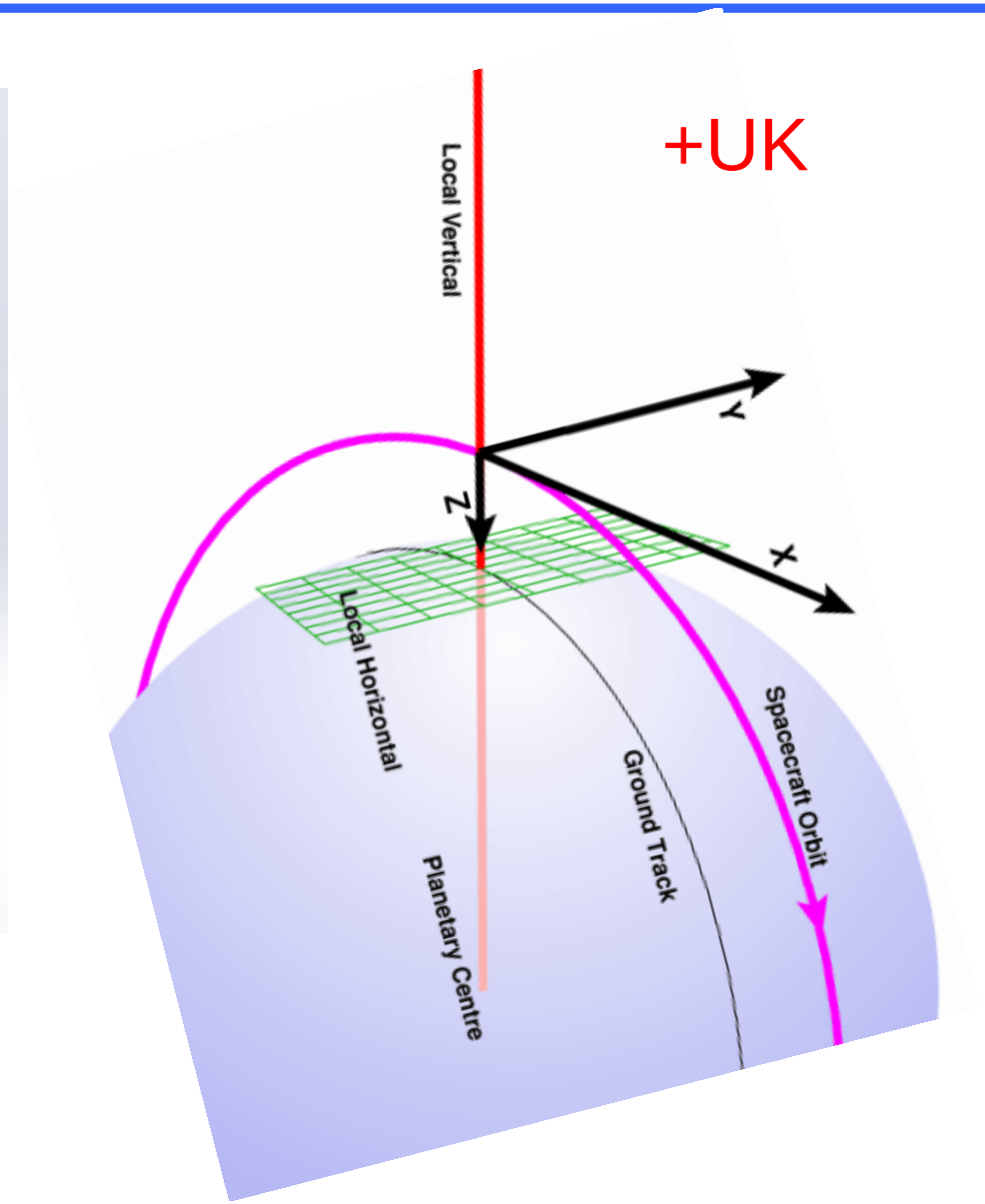
Targets
Primary: isolated pulsars
Secondary: accreting pulsars, microquasars, blazars

Pathfinder of XTP

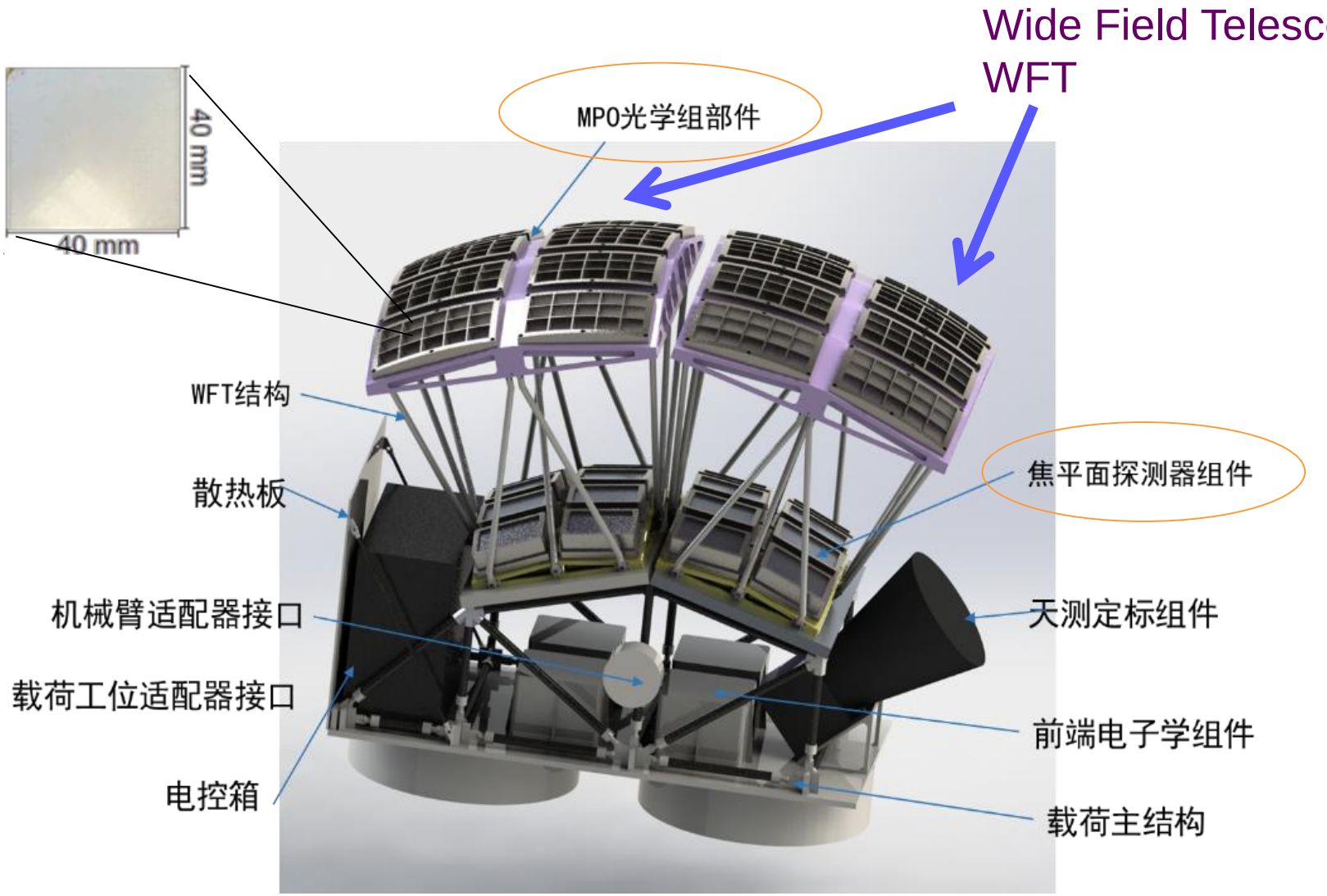
X-ray All Sky Monitor (XASM): 2020 launch



FOV: 61ºx36.9º

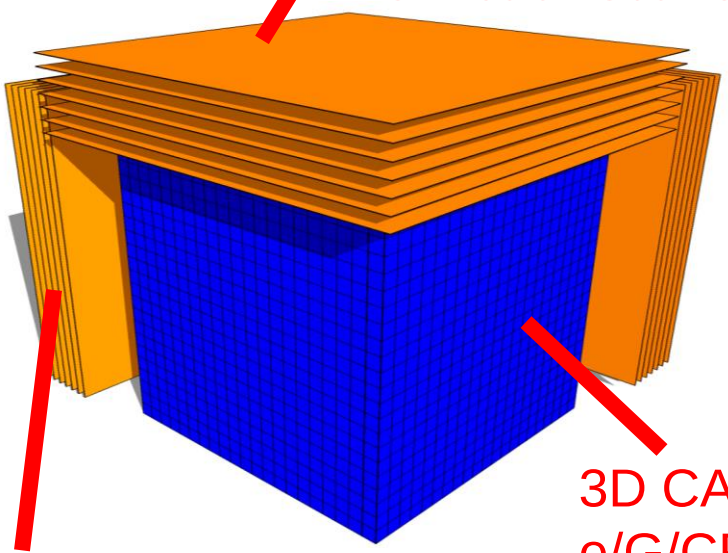


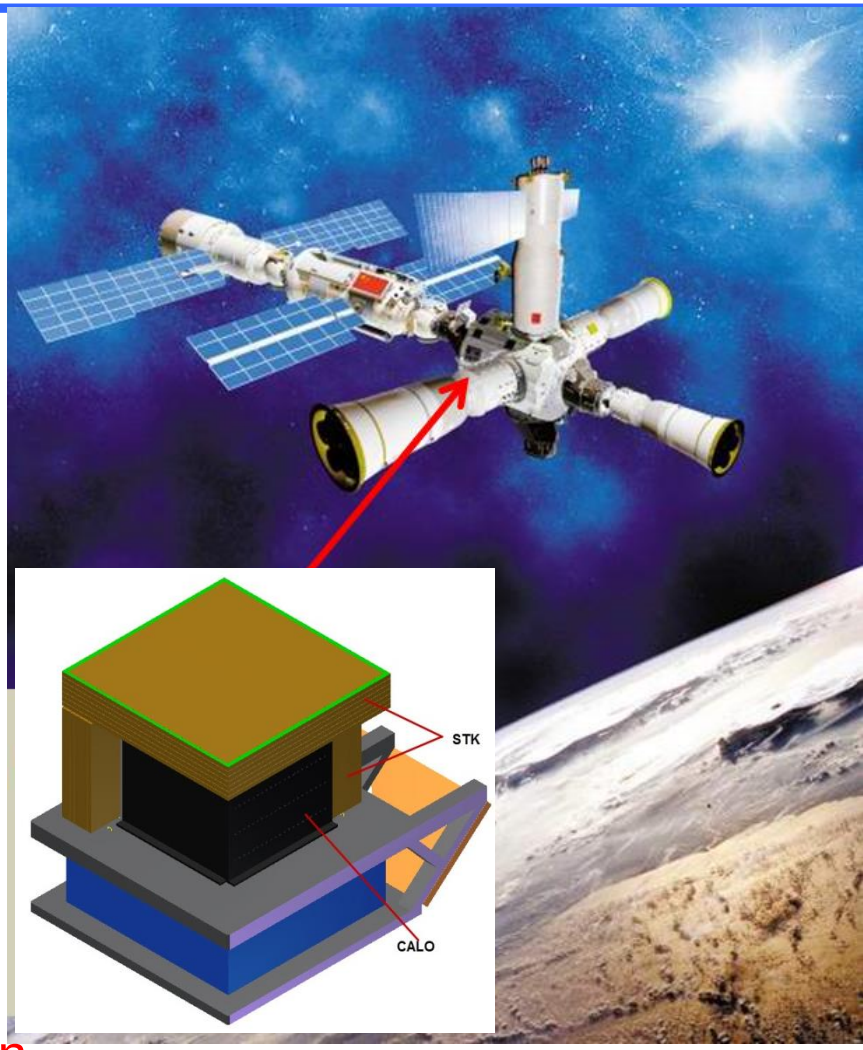
XASM Design: Lobster Eye Optics



HERD：3D Calo & 5-Side Sensitive

n10X acceptance than most others, but weight 2.3 T ~1/3 AMS





+ Italy, Switzerland, Sweden

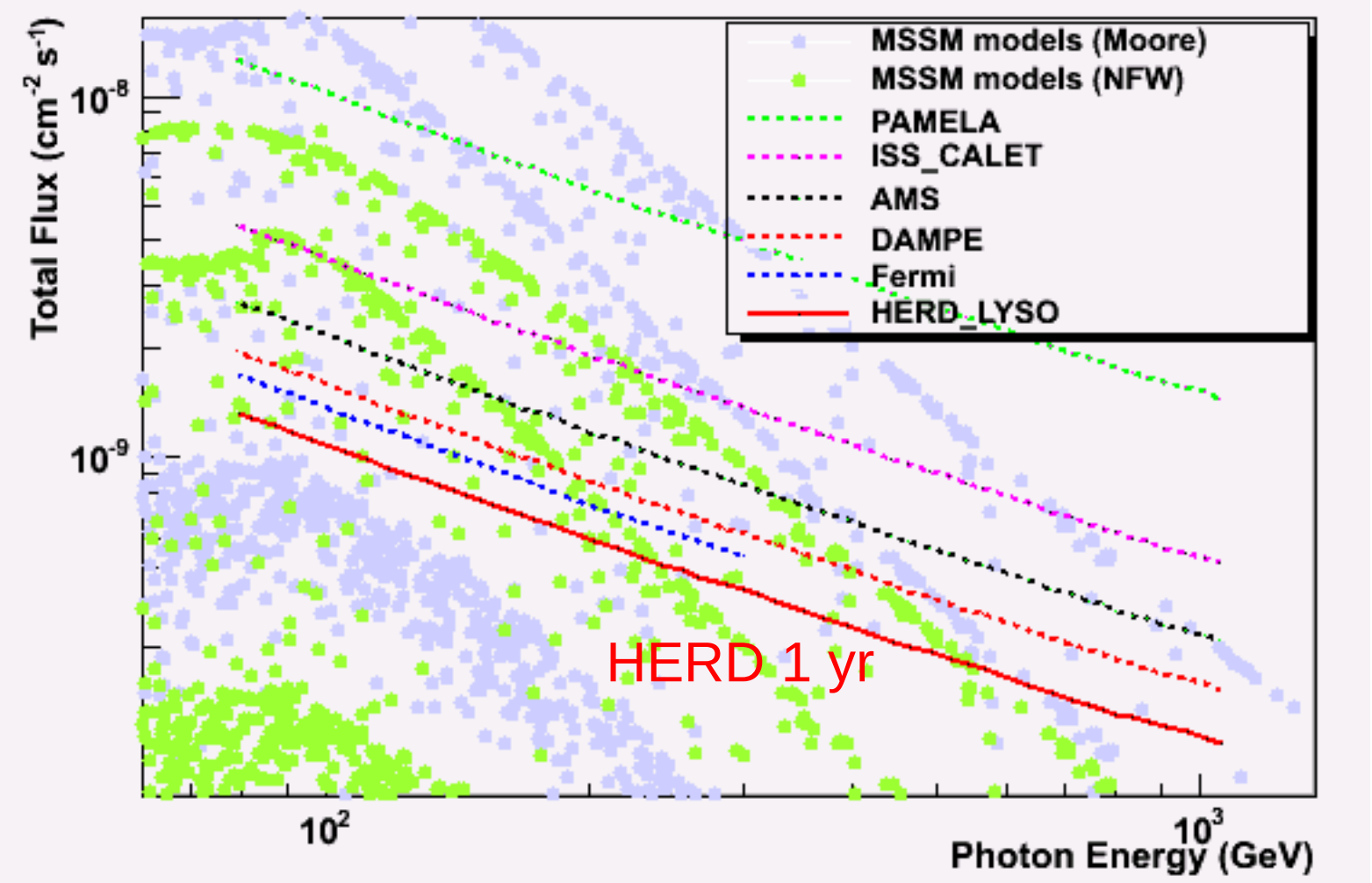

background
Gamma-ray
HERD
electron
proton
He
Dark matter particle

Expected performance of HERD

γ/e energy range (CALO)	tens of GeV-10TeV
nucleon energy range (CALO)	up to PeV
γ/e angular resol. (Si-strips)	0.1^{o}
nucleon charge resol. (Si-strips)	0.1-0.15 c.u
γ/e energy resolution (CALO)	<1%@200GeV
proton energy resolution (CALO)	20%
e/p separation power (CALO)	$<10^{-5}$
electron eff. geometrical factor (CALO)	3.7 m^2sr@600 GeV
proton eff. geometrical factor (CALO)	2.6 m^2sr@400 TeV

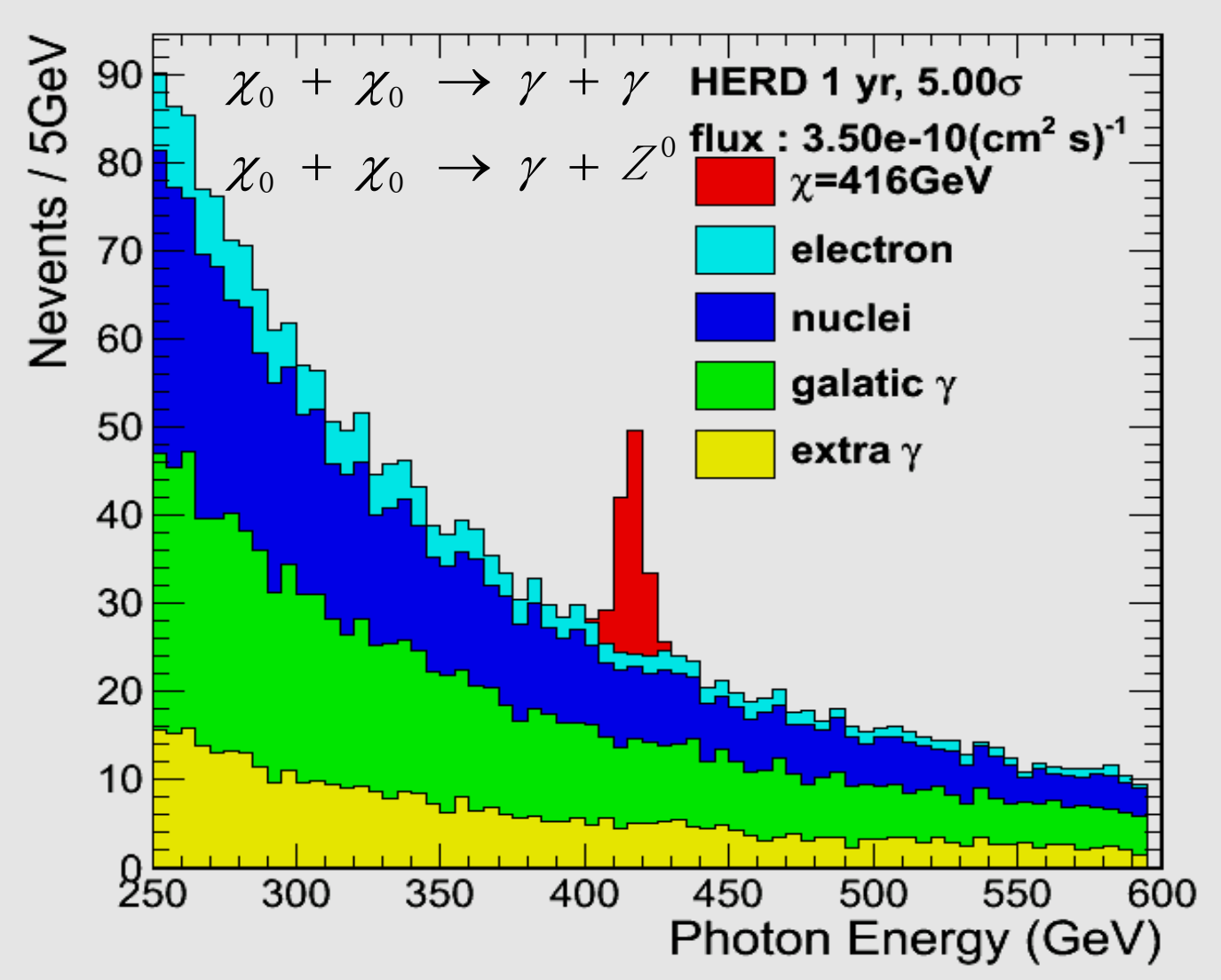
2025 launch?

HERD sensitivity to gamma-ray line

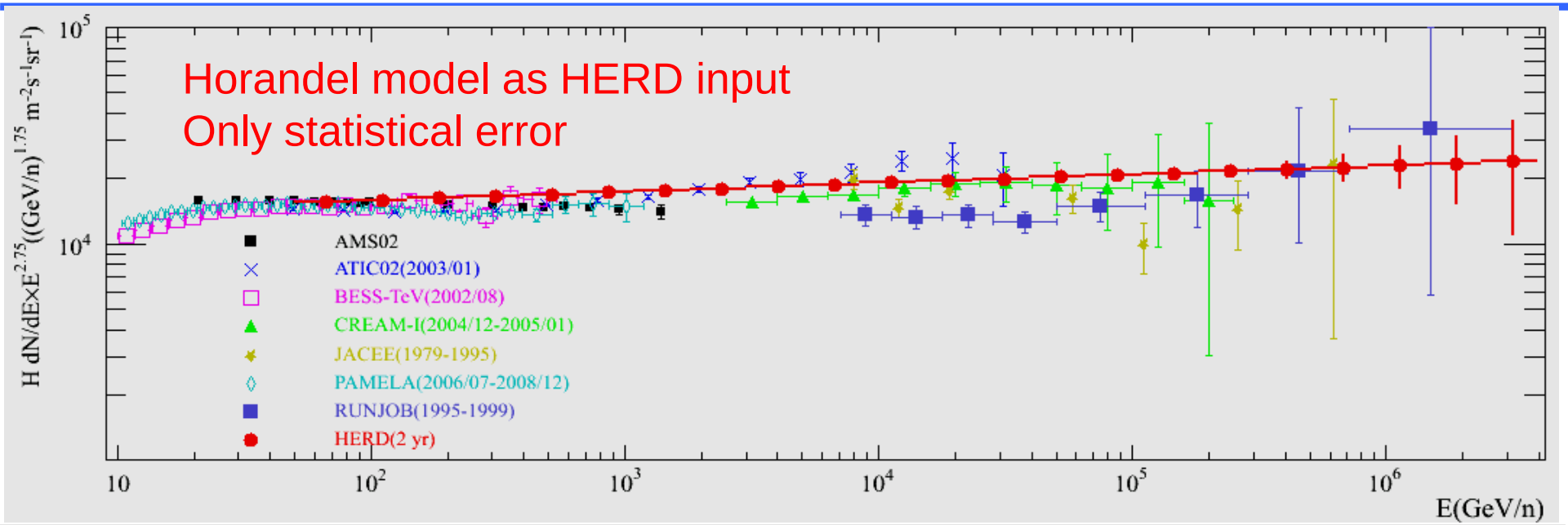


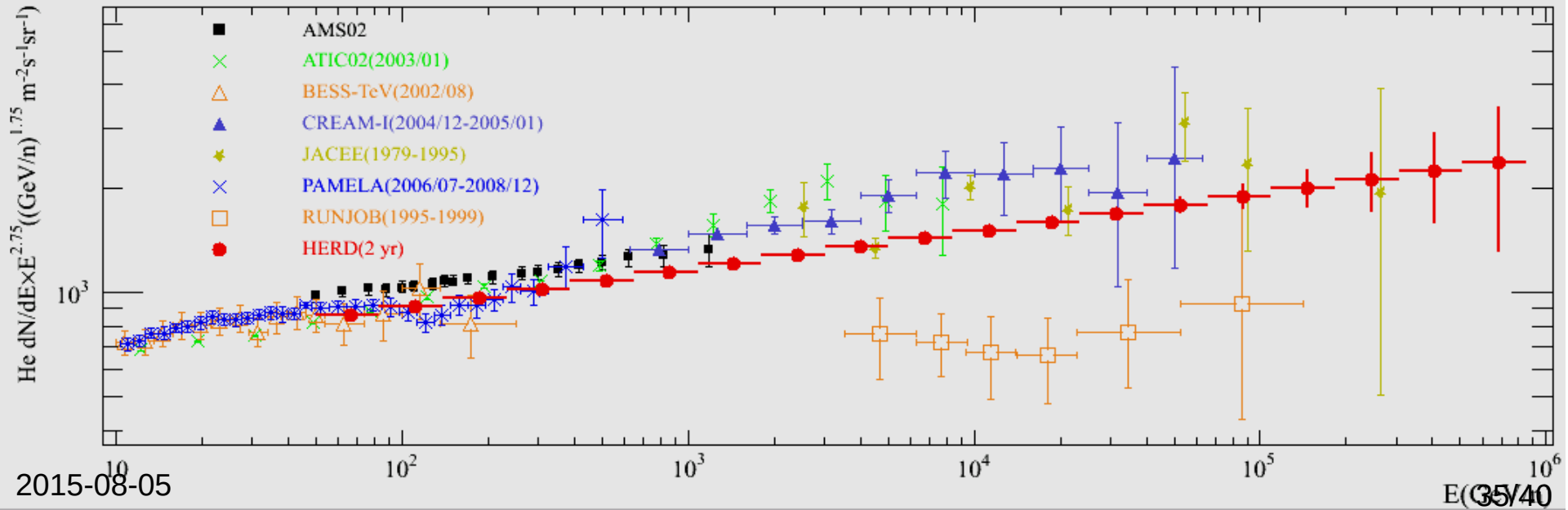
PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2021;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2020-2021

DM annihilation line of HERD

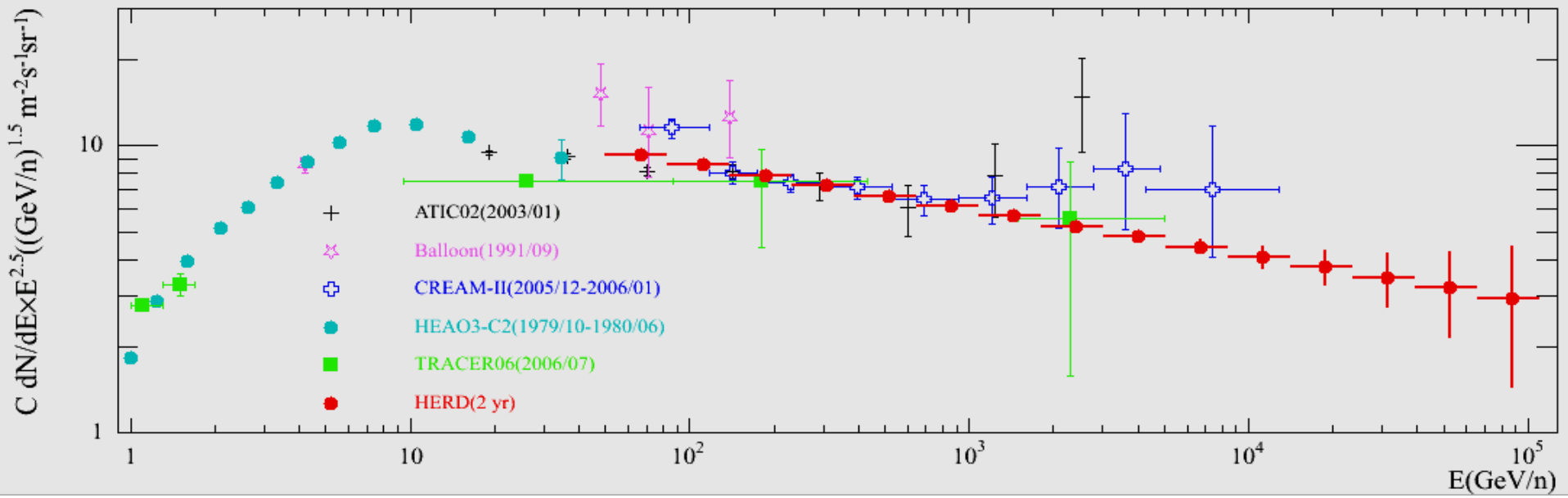


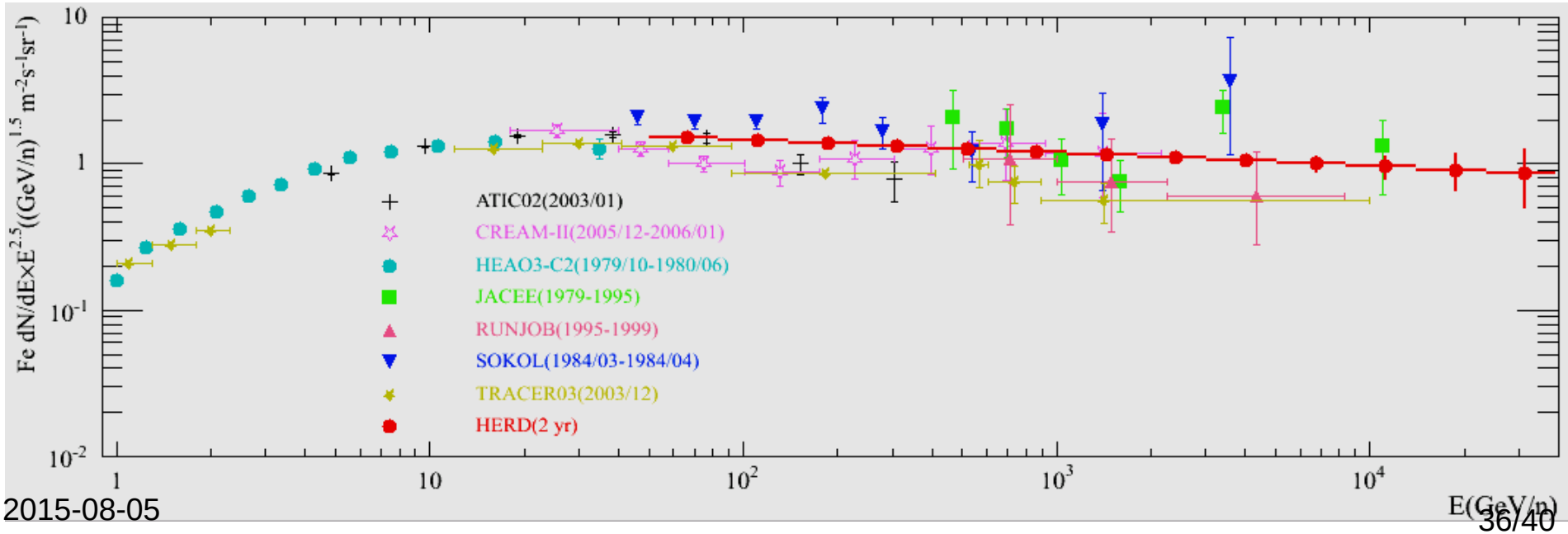
Expected HERD Proton and He Spectra





Expected HERD Spectra of C and Fe

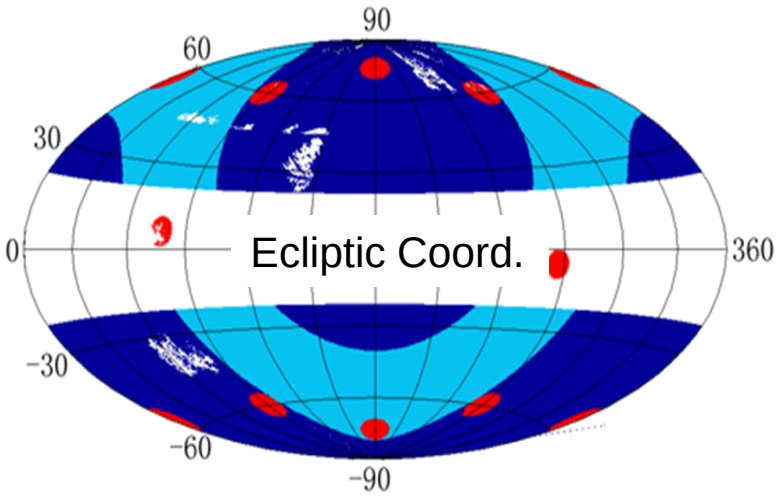




Chinese Space Station Optical Survey

- 25000□° imaging survey: 250-1050nm, ≥6 filters, g, r, & i ≥ AB25 mag (5σ, point source)
- 800□° deep imaging survey: g, r, & i ≥ AB26.5 mag
- 10000□° medium & high galactic latitude slitless spectroscopy survey: g, r, & i continuum ≥ AB21 mag

2022?



World-wide contributions in science definition

Survey Science

Cosmology: dark energy, dark matter, gravity, large-scale structure, neutrinos, primordial non-Gaussianity…

AGNs: high-z AGNs, clustering, dual AGNs, variability, UV excess, host galaxies…

Galaxies: formation & evolution, mergers, high-zs, dwarfs, LSBs, near field, halos properties…

Milky Way: structure, satellites, dust, extinction…

Stellar science: formation, dwarfs, metal poor…

Solar system (high inclination): TNO、NEA…

Astrometry: reference frame, star clusters…

…

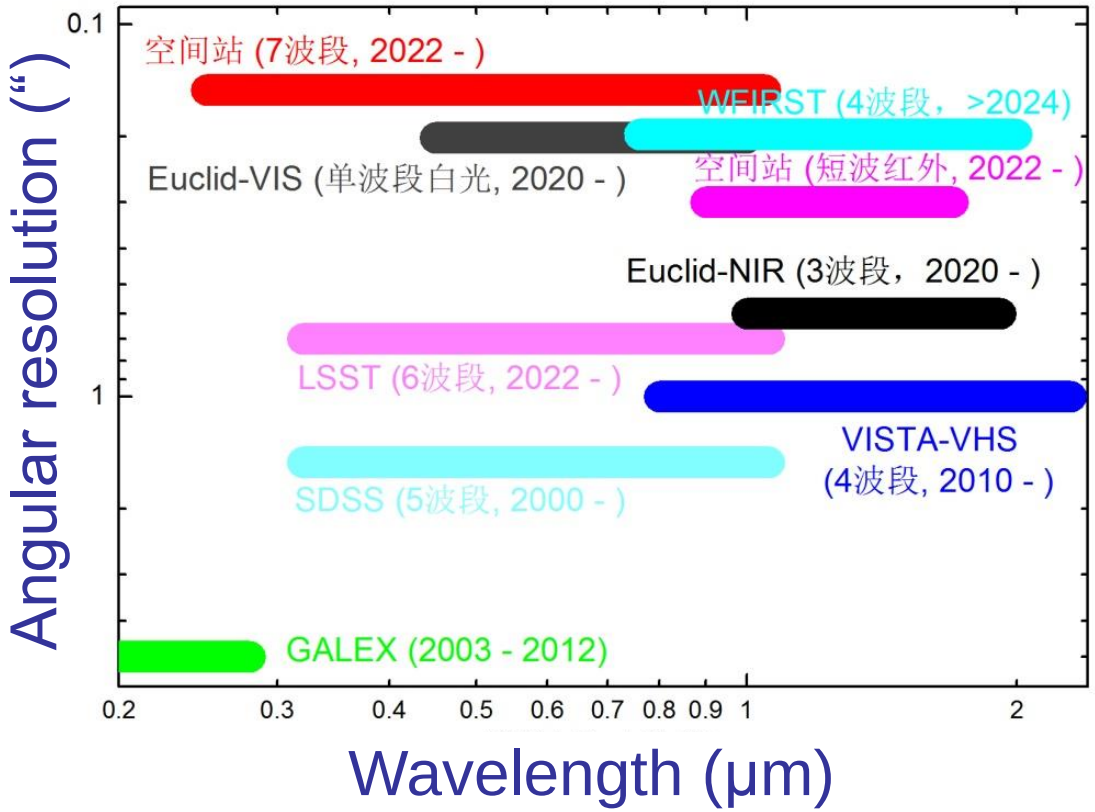
Comparison with Other Surveys

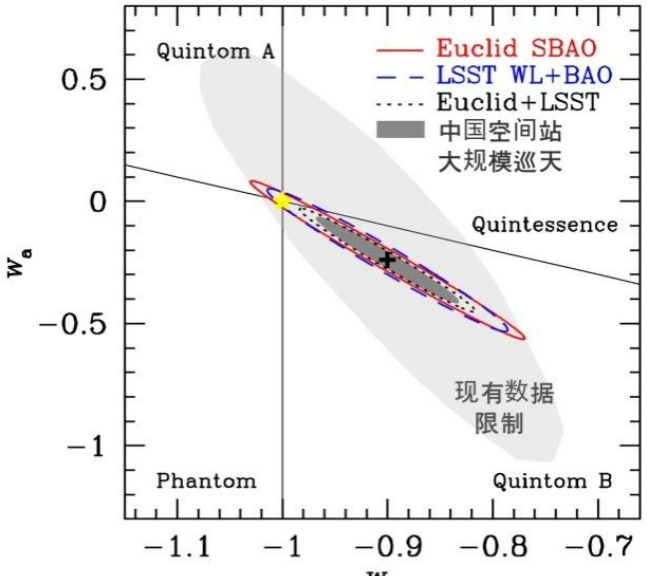
Project	Site	Launch/Op	FoV	R_{EE80}	Num pixels	Area	Wavelength	Num Filter	Spec
			deg^2	″	10^9	deg^2	nm		
Space Station	LEO	2022	1.1 0.002	0.15 0.25	2.5 0.002	25000 -	250—1050 900—1700	7 2	yes yes
Euclid	L2	2020	0.56 0.55	>0.2 0.6	0.6 0.07	15000	550—920 1000—2000	1 3	no yes
WFIRST	GEO	≥2024	0.28	>0.2	0.3	2400	927—2000	4	yes
LSST	Chile	2022	9.6	>0.7	3.2	20000	320—1050	6	no

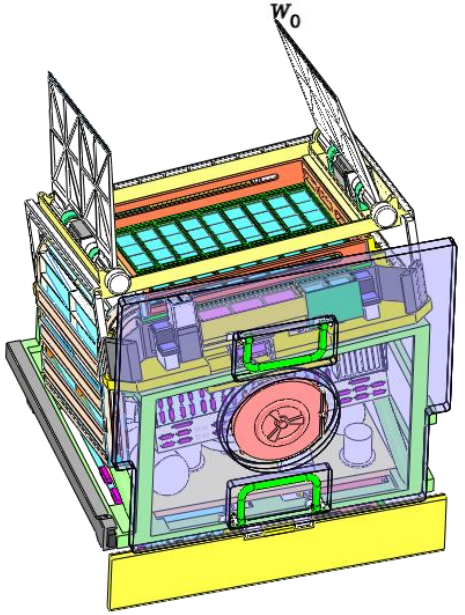
5σ point source limiting AB mag of Space Station Survey

	Exp	NUV	u	g	r	i	z	Y
Imaging	2×150s	25.5	25.5	26.1	25.9	25.7	25.5	24.7
Deep Imaging	7×200s	26.5	26.5	27.1	26.8	26.7	26.5	25.7
Slitless Spec	2×200s	20.3	21.0	21.3	21.4	21.4	21.5	21.0

Comparison with Other Surveys







The Chinese space station optical survey is very competitive among its peers, and its capability, especially high-resolution near-UV imaging and slitless spectroscopy in the optical, is unique and highly complementary to other surveys.

Summary

- Astronomy satellite
  - Approved: DArk Matter Particle Exploration (DAMPE, 2015), Hard X-ray Modulation Telescope (HXMT, 2016), Space Variable Object Monitor (SVOM, 2021)
  - Phase 0/A: Einstein Probe (EP: 2020), X-ray Timing and Polarization (XTP: <2025?)
- Manned Space Flight Program
  - Approved: Gamma-ray burst polarization (POLAR, 2016), NEATER (2020), XASM (2020) , Space Station Optical Survey (2022?)
  - Phase 0/A: HERD (2025?)

Significant international contributions to all missions!