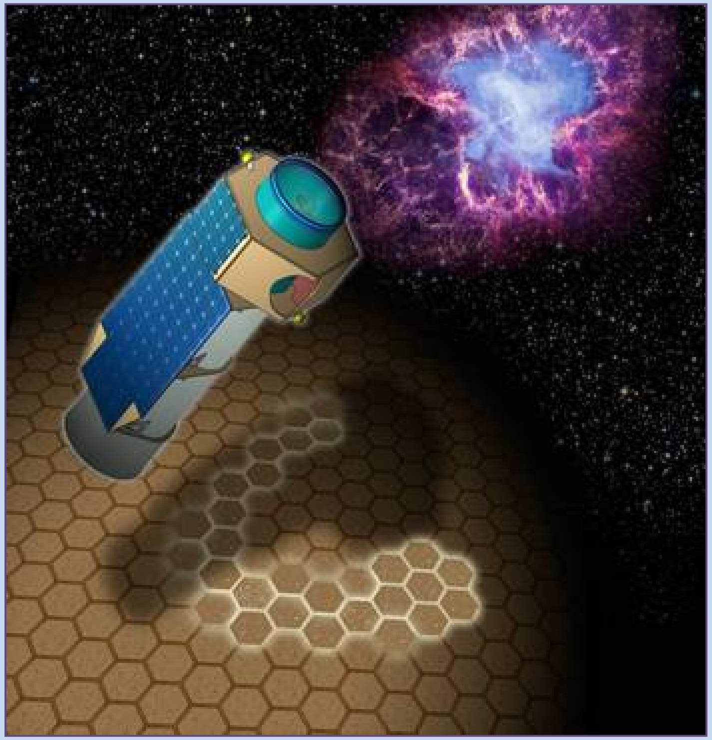
XIPE e IXPE



Paolo Soffitta
IAPS/INAF Roma

Picking the right direction
Xipe

www.isdc.unige.ch/xipe

Polarimetria X ad immagine

XIPE e IXPE

Polarization from celestial sources may derive from:

- **Emission processes themselves: cyclotron, synchrotron, non-thermal bremsstrahlung**

(Westfold, 1959; Gnedin & Sunyaev, 1974; Rees, 1975)

- **Scattering on aspherical accreting plasmas: disks, blobs, columns.**

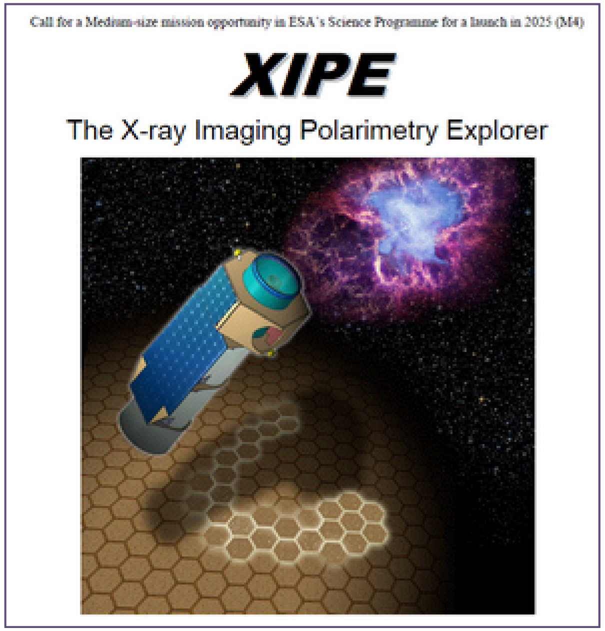
(1975; Sunyaev & Titarchuk, 1985; Mészáros, P. et al. 1988)

- **Vacuum polarization and birefringence through extreme magnetic fields**

(Gnedin et al., 1978; Ventura, 1979; Mészáros & Ventura, 1979)

XIPE e IXPE

Contesto internazionale



Call for a Medium-size mission opportunity in ESA's Science Programme for a launch in 2025 (M4)

XIPE

The X-ray Imaging Polarimetry Explorer

3 missions of X-ray polarimetry now in competition between ESA and NASA

December 18, 2014

IXPE

Imaging
X-Ray
Polarimetry
Explorer

Principal Investigator:
Dr. Martin C. Weisskopf, MSFC
Authorizing Official:
Patrick Scheuermann, Director MSFC

Small Explorer Proposal

Marshall Space Flight Center

Lead Scientist: Paolo Soffitta (IAPS/INAF)

PI Martin Weisskopf @ MSFC/NASA

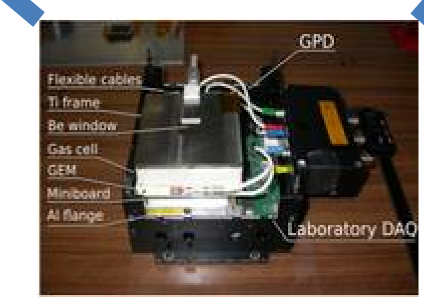
ESA M4.

Competitors:

THOR: a mission to study turbolence on Solar Wind (A. Vaivads IRF/Sweden)

Ariel: a mission for the spectroscopy of Exoplanets G. Tinetti UCL/UK.

Decision in May/June 2017



3 GPDs al fuoco di 3 ottiche per raggi X

NASA SMEX.

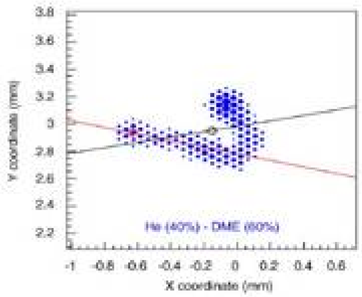
Competitors

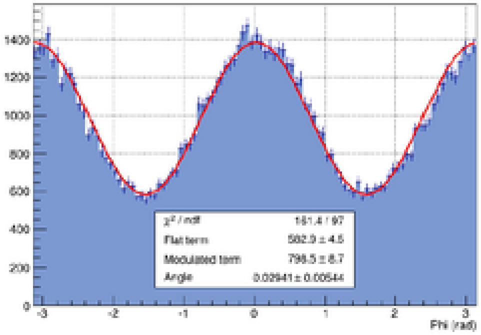
PRAXYS: a Mission of X-ray Polarimetry based on TPC. PI K. Jahoda @ NASA/GSFC

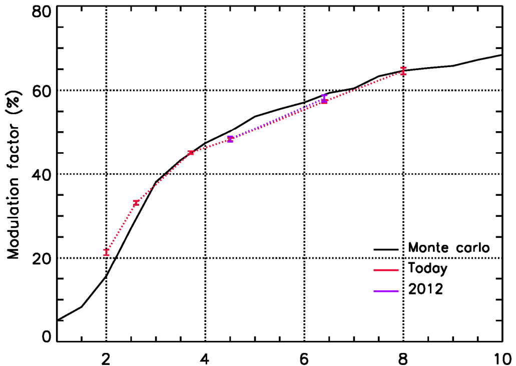
SPHEREx: a Mission of All Sky Survey of NearIR spectroscopy. PI James Bock @ CalTech

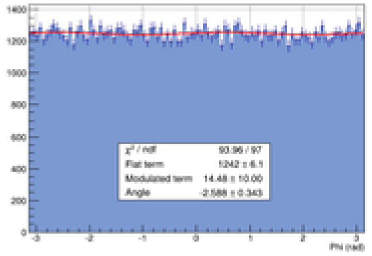
Why this is now possible

The Gas Pixel Detector

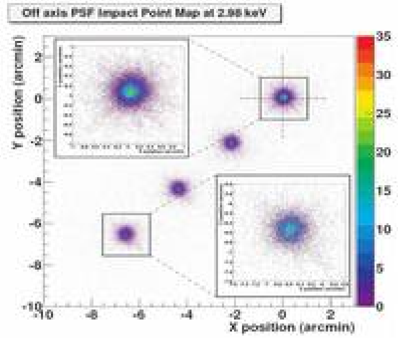




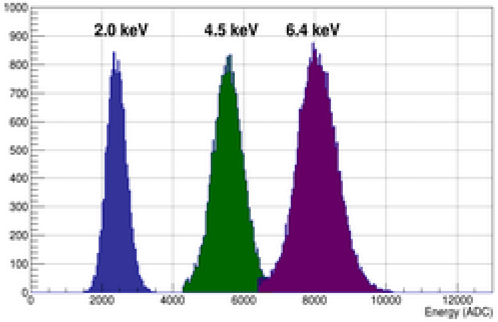


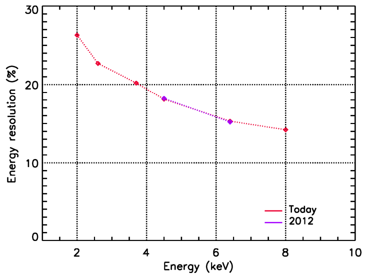


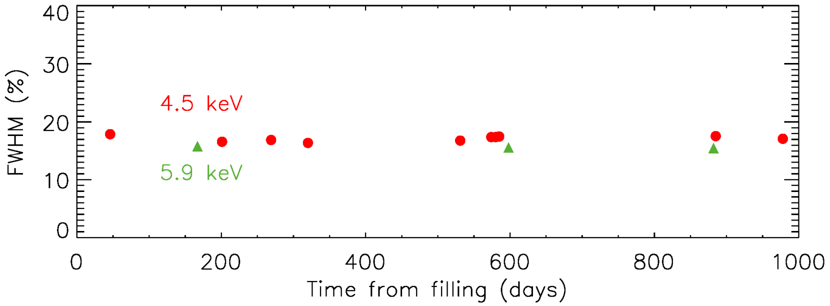
Polarimetria



Immagine



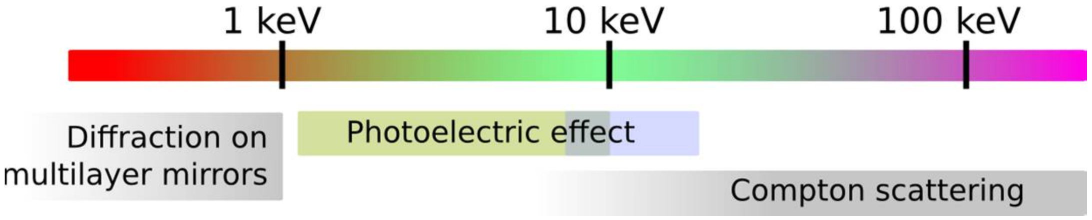




Spettroscopia

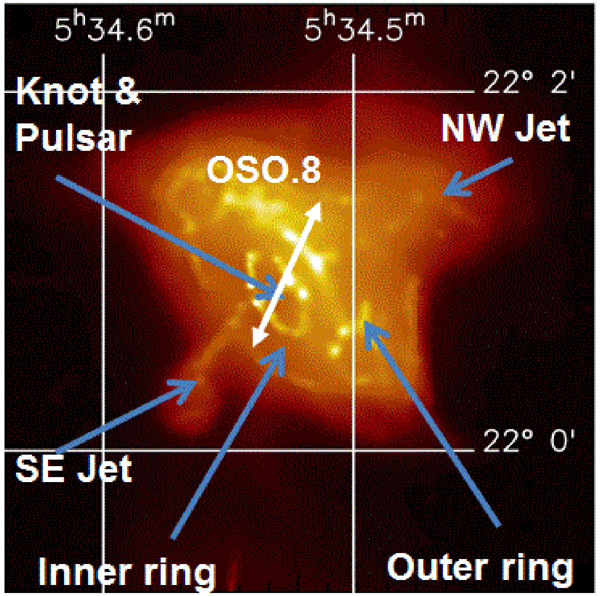
The XIPE energy band

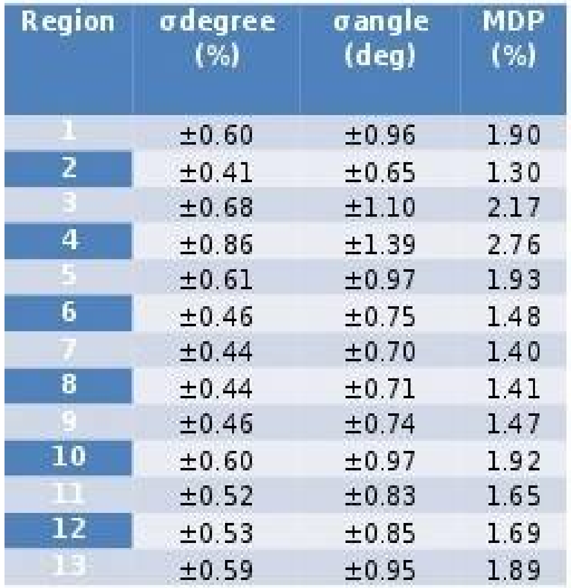
Scientific goal	Sources	< 1keV	1-10	> 10 keV
Acceleration phenomena	PWN	yes (but absorption)	yes	yes
	SNR	no	yes	yes
	Jet (Microquasars)	yes (but absorption)	yes	yes
	Jet (Blazars)	yes	yes	yes
Emission in strong magnetic fields	WD	yes (but absorption)	yes	difficult
	AMS	no	yes	yes
	X-ray pulsator	difficult	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



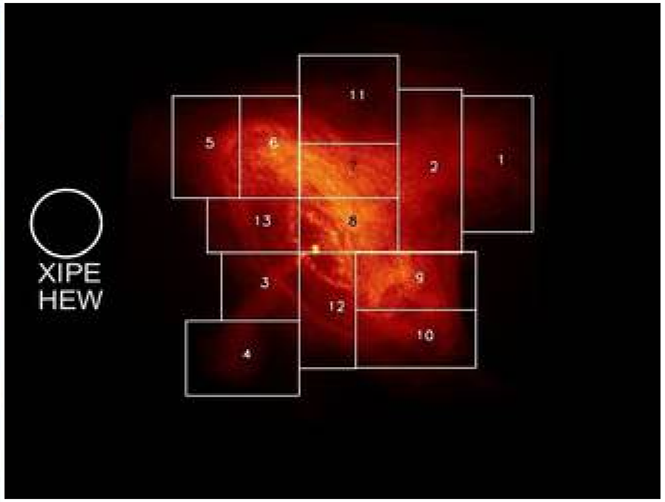
XIPE scientific goals

Astrophysics: Acceleration: PWN & SNR



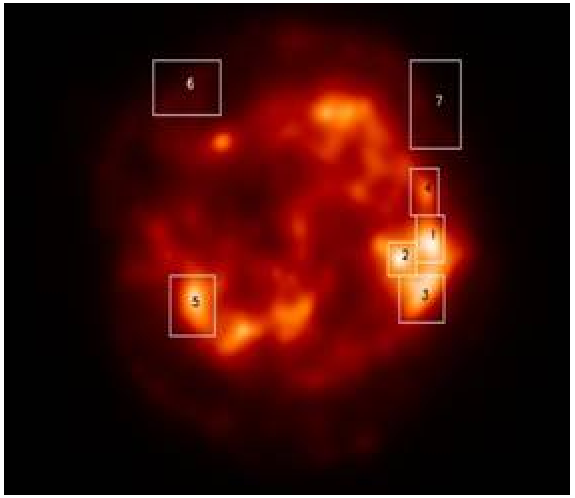


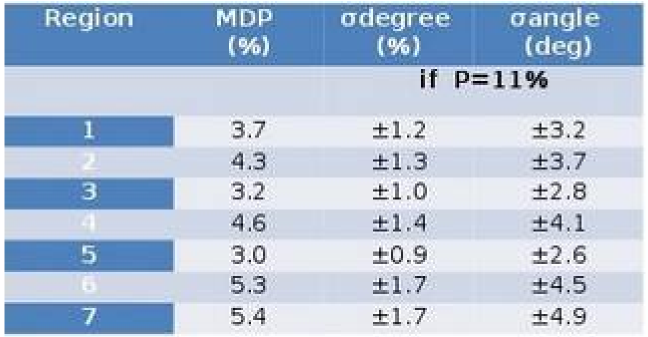
Region	σdegree (%)	σangle (deg)	MDP (%)
1	±0.60	±0.96	1.90
2	±0.41	±0.65	1.30
3	±0.68	±1.10	2.17
4	±0.86	±1.39	2.76
5	±0.61	±0.97	1.93
6	±0.46	±0.75	1.48
7	±0.44	±0.70	1.40
8	±0.44	±0.71	1.41
9	±0.46	±0.74	1.47
10	±0.60	±0.97	1.92
11	±0.52	±0.83	1.65
12	±0.53	±0.85	1.69
13	±0.59	±0.95	1.89



20 ks with XIPE

What is the role of the magnetic field (turbulent or not?)





Region	MDP (%)	σdegree (%)	σangle (deg)
		if P=11%	
1	3.7	±1.2	±3.2
2	4.3	±1.3	±3.7
3	3.2	±1.0	±2.8
4	4.6	±1.4	±4.1
5	3.0	±0.9	±2.6
6	5.3	±1.7	±4.5
7	5.4	±1.7	±4.9

Many sources in each class available for XIPE

100 – 150 quoted in the proposal:

- 500 days of net exposure time in 3 years;
- average observing time of 3 days;
- re-visiting for some of those.

What number for each class?

Target Class	T_{tot} (days)	T_{obs}/source (Ms)	MDP (%)	Number in 3 years	Number available
AGN	219	0.3	< 5	73	127
XRBs (low+high mass)	91	0.1	< 3	91	160
SNRe	80	1.0	< 15 % (10 regions)	8	8
PWN	30	0.5	<10 % (more than 5 regions)	6	6
Magnetars	50	0.5	< 10 % (in more than 5 bins)	10	10
Molecular clouds	30	1-2	< 10 %	2 complexes or 5 clouds	2 complexes or 5 clouds
Total	**500**			**193**	**316**

From catalogues: Liu et al. 2006, 2007 for X-ray binaries; and XMM slew survey 1.6 for AGNs.

Working groups set: about 300 scientists signed for participation.

WG1. Acceleration mechanisms: Giampiero Taglaferri(1), Jacco Vink(2)
(1) Osservatorio Astronomico di Brera INAF, Italy, (2) Astronomical Institute Anton Pannekoek, The Netherlands

WG1.1 **Pulsar Wind Nebulae**: Emma de Ona Wilhelmi , ICE, Spain
WG1.2 **Supernova Remnants**: **Andrei Bykov,** Ioffe Physical-Technical Institute, Russia
WG1.3 **Blazars: Ivan Agudo, Instituto** de Astrofísica de Andalucía, Spain
WG1.4 **Micro-QSO**s: **Elena Gallo**, University of California, Santa Barbara, USA
WG1.5 **Gamma Ray** Bursts: **Carol Mundell**, University of Bath, UK
WG1.6 **Tidal Disruption** Events: **Immacolata Donnarumma**, IAPS/INAF, Italy
WG1.7 **Active Stars**: **Nicholas Grosso**, Astronomical Observatory in Strasbourg, France
WG1.8 **Clusters of Galaxy**: **Sergey Sazonov**, Space Research Institute, Russian Academy of Sciences, Russia

WG2. Magnetic Fields in compact objects: Andrea Santangelo (1), Silvia Zane (2)
(1) Institut für Astronomie und Astrophysik Tuebingen, (2) University College London/MSSL, UK

WG2.1 **Magnetic Cataclismic Variables**: **Domitilla De Martino**, Osservatorio di Capodimonte, taly
WG2.2 **Accreting Millisecond Pulsars**: **Juri Poutanen**, Finland Tuorla Observatory, U. of Turku,Finland
WG2.3 **Accreting X-ray Pulsars**: **Victor Doroshenko**, IAAT, Germany
WG2.4 **Magnetars**: **Roberto Turolla**, University of Padua, Italy

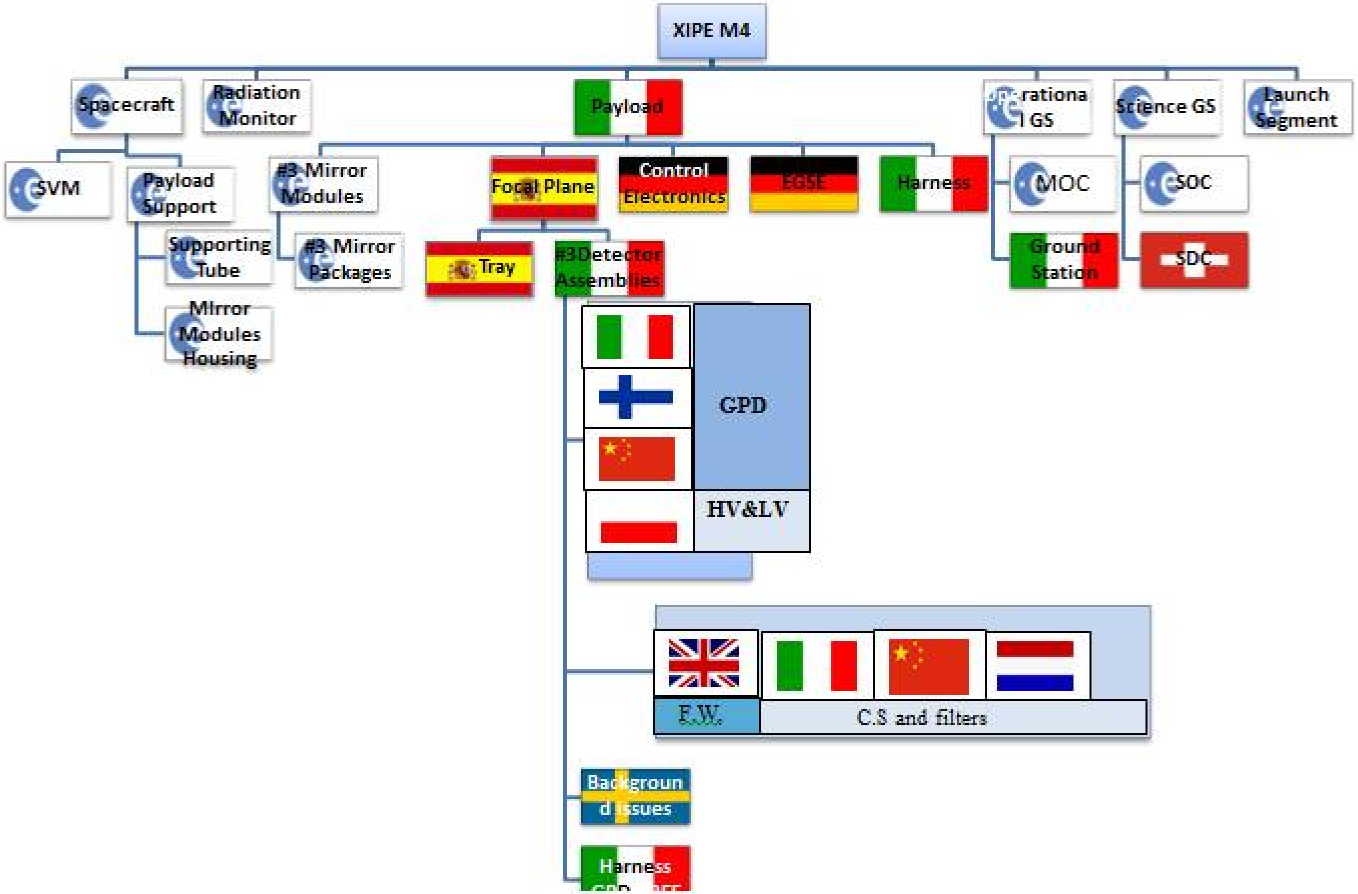
WG3. Scattering in aspherical geometries and accretion Physics: Eugene. Churazov (1), Rene‘ Goosmann(2)
(1)Max-Planck-Institut für Astrophysik, Germany (2) Astronomical Observatory in Strasbourg, France

WG3.1 **X-ray binaries and QPOs**: **Julien Malzac**, CESR/CNRS, France
WG3.2 **AGNs**: **Pierre Olivier Petrucci**, Institut de Planétologie et d’Astrophysique de Grenoble, France
WG3.3 **Molecular Clouds & SgrA***: **Frédéric Marin**, Astronomical Institute of the Academy of Sciences, Czech Republic
WG3.4 **Ultra Luminous X-ray sources**: **Hua Feng**, Tsinghua University, Beijing, China

WG4. Fundamental Physics: Enrico Costa (1), Giorgio Matt (2)
(1) INAF/IAPS, Italy (2) Universita' Roma Tre, Italy

WG4.1 **QED and X-ray polarimetry**: **Rosalba Perna**, Stony Brook University, USA
WG4.2 **Strong Gravity: Jiří Svoboda**, Astronomical Institute of the Academy of Sciences, Czech Republic
WG4.3 **Quantum Gravity**: **Philip E. Kaaret**, Iowa University, USA
WG4.4 **Axion-like particles**: **Marco Roncadelli**, University of Pavia , Italy

All Europe and more



XIPE M4

Spacecraft
Radiation Monitor
Payload
rationa l GS
Science GS
Launch Segment

SVM
Payload Support
Supporting Tube
Mirror Modules Housing
#3 Mirror Modules
#3 Mirror Packages
Focal Plane
Tray
#3Detector Assemblies
Control Electronics
EGSE
Harness
MOC
Ground Station
SOC
SDC

GPD
HV&LV

F.W.
C.S and filters

Background issues
Harness

The distribution of activities

Contesto Nazionale: Istituti e Universita' coinvolte e contributo hardware

XIPE M4/ESA

IAPS/INAF
INFN-Pi
OAB/INAF
Universita' Roma Tre
(Univ. Di Padova, Oss. Di Capodimonte, Oss. Astrofisico di Acetri)

- **Gas Pixel Detectors** (INFN-PI)
- **Back End Electronics** (INFN-Pi)
- **Calibrazione completa del Detector** (IAPS/INAF)
- **Malindi G/S** (ASI)
- **Partecipazione alle calibrazioni End-to-END** (OAB/INAF; IAPS/INAF)
- **Partecipazione al design e alla qualifica delle ottiche (Telescope Advisory Group)** OAB/INAF
- **P/O presso il PI di missione** (IAPS/INAF)
- **Partecipazione e guida dei WG scientifici** (Roma Tre, IAPS/INAFOAB/INAF Uni Padova, OAA/INAF)

Contesto internazionale

- IAPS/INAF (HW, Cal)
- INFN (HW, Cal)
- Universita' ROMA TRE (Science)
- MSFC/NASA (PI, Optics, SOC)
- UC-LASP (MOC)
- McGILL University (Science)
- Stanford University (Science)

IXPE NASA/SMEX

Contributo Italiano

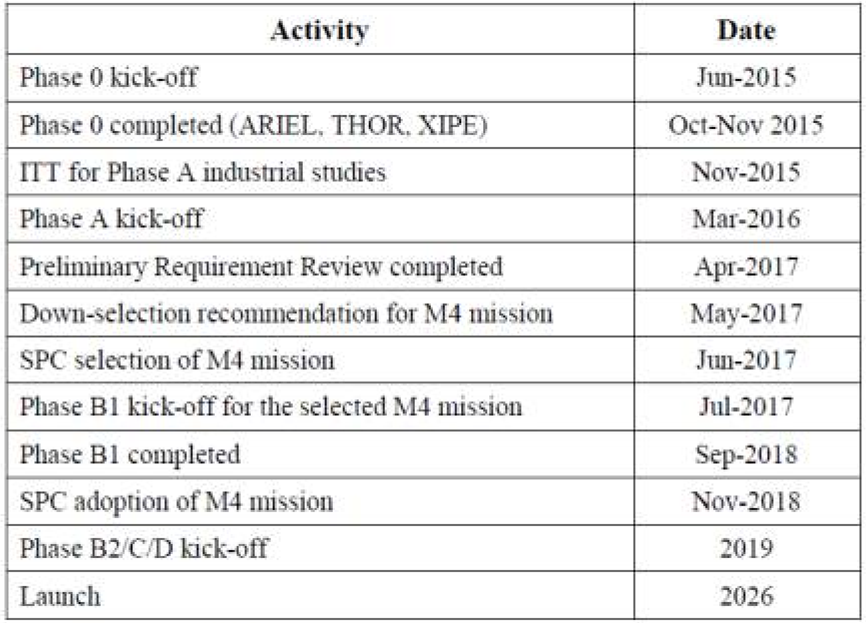
- Instrument
  - Gas Pixel Detector (EM 3, FU, 1 FS)
  - Filter Wheel + Cal Sources (EM, 3 FU, 1 FS)
  - Back End Electronics (EM, 3 FU, 1 FS)
  - P/L Computer (EM, 1 PFM)
  - P/L Simulator
  - Test Equipments

- Attivita':
- Integrazione e test DU (INFN Pi)
- Calibrazione Stand Alone (IAPS/INAF)
- Partecipazione alla Calibrazione End-to-End (IAPS/INAF & INFN)
- Partecipazione alla definizione degli obiettivi scientifici e all'analisi dei dati

XIPE & IXPE

Timelines

ESA/M4:
CaC 450 Meuros

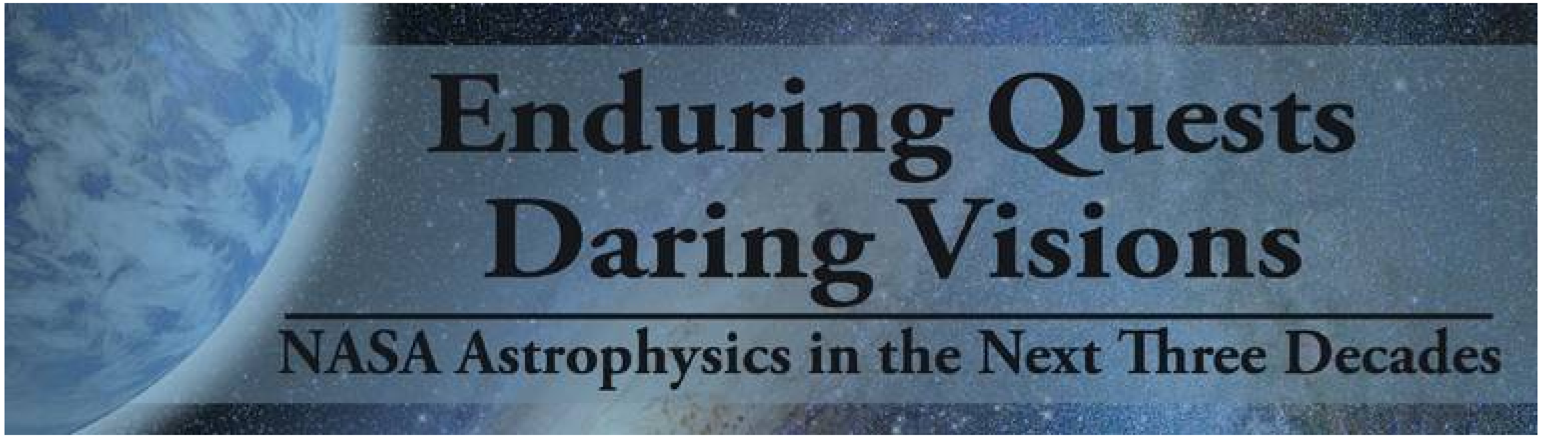


Activity	Date
Phase 0 kick-off	Jun-2015
Phase 0 completed (ARIEL, THOR, XIPE)	Oct-Nov 2015
ITT for Phase A industrial studies	Nov-2015
Phase A kick-off	Mar-2016
Preliminary Requirement Review completed	Apr-2017
Down-selection recommendation for M4 mission	May-2017
SPC selection of M4 mission	Jun-2017
Phase B1 kick-off for the selected M4 mission	Jul-2017
Phase B1 completed	Sep-2018
SPC adoption of M4 mission	Nov-2018
Phase B2/C/D kick-off	2019
Launch	2026

Table 1: Tentative timeline for M4 activities

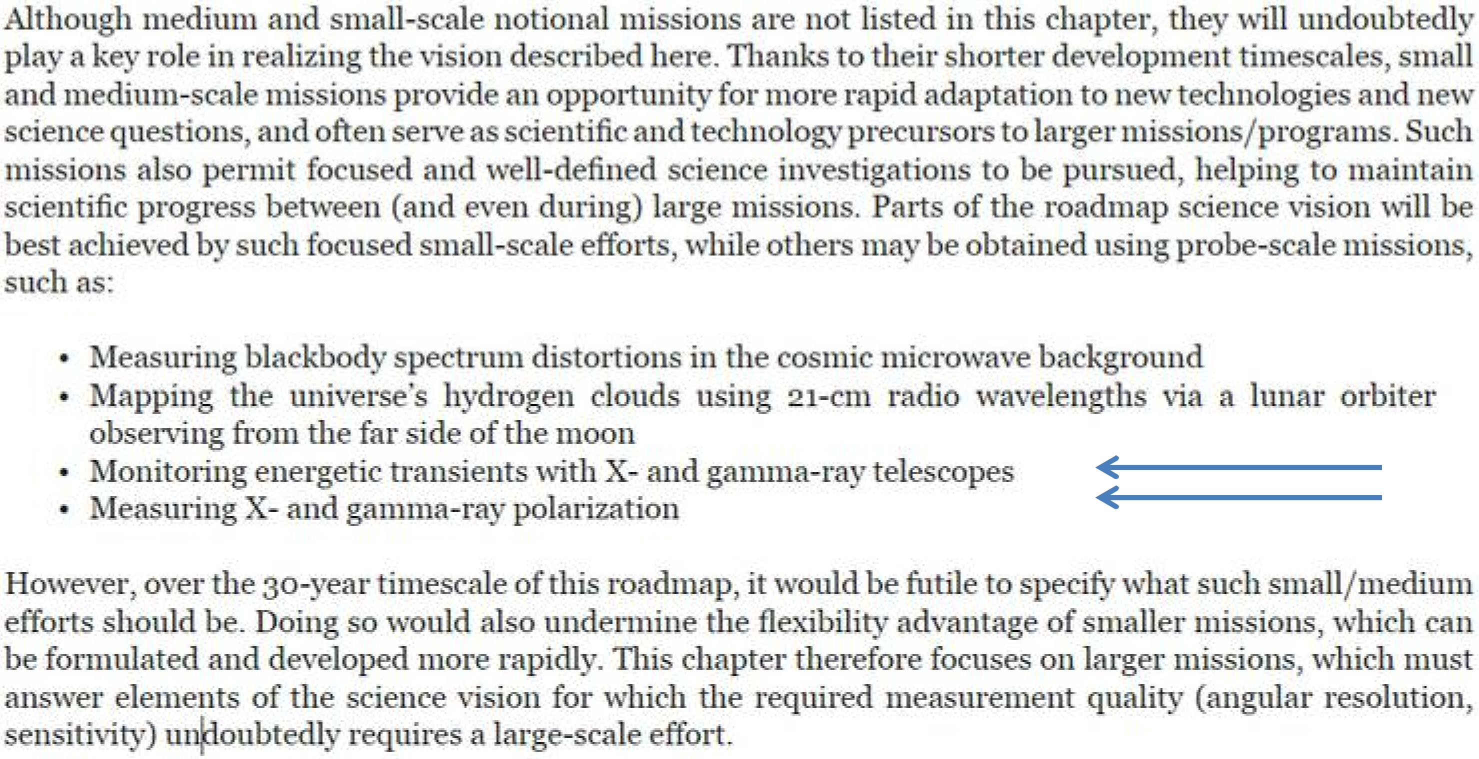
NASA /SMEX
CaC 175 M$

- Phase A report due on 19th July 2016
- Site Visit on 21st November 2016
- NASA decision January 2017
- Launch end 2020



Enduring Quests
Daring Visions

NASA Astrophysics in the Next Three Decades



Although medium and small-scale notional missions are not listed in this chapter, they will undoubtedly play a key role in realizing the vision described here. Thanks to their shorter development timescales, small and medium-scale missions provide an opportunity for more rapid adaptation to new technologies and new science questions, and often serve as scientific and technology precursors to larger missions/programs. Such missions also permit focused and well-defined science investigations to be pursued, helping to maintain scientific progress between (and even during) large missions. Parts of the roadmap science vision will be best achieved by such focused small-scale efforts, while others may be obtained using probe-scale missions, such as:

- Measuring blackbody spectrum distortions in the cosmic microwave background
- Mapping the universe's hydrogen clouds using 21-cm radio wavelengths via a lunar orbiter observing from the far side of the moon
- Monitoring energetic transients with X- and gamma-ray telescopes ←
- Measuring X- and gamma-ray polarization ←

However, over the 30-year timescale of this roadmap, it would be futile to specify what such small/medium efforts should be. Doing so would also undermine the flexibility advantage of smaller missions, which can be formulated and developed more rapidly. This chapter therefore focuses on larger missions, which must answer elements of the science vision for which the required measurement quality (angular resolution, sensitivity) undoubtedly requires a large-scale effort.

END