The eXTP Mission

Studying the behavior of matter and light under extreme conditions of density, gravity and magnetism

Presentazione di nuove iniziative
INFN Pisa - 19 Giugno 2020

eXTP - enhanced X-ray Timing and Polarimetry Mission

A flagship X-ray astronomy mission led by Chinese Academy of Science

- Launch in late 2027, currently in phase B

Payload concept

- Short focal-length for multiple modules
- Deployable panel for collimated modules
- Polarimeter with imaging capability
- Wide field monitor

A Large China-Italy cooperation opportunity

Parameter	Value
Orbit	550 km, <2.5° inclination
Launcher	Long-March CZ-7 + upper stage, from Wenchang
Mass	4500 kg
Power	3.6 kW
Telemetry	3.2 Tb/day (X-band)
Ground Stations	Sanya, Malindi
Pointing	3-axis stabilized, < 0.01° (3-sigma)
Sky visibility	50% (goal 75%)
Mission Duration	5 years (goal 8 years)
Launch date	2027

- Italy is PI of the LAD (Large Area Detector) instrument, coPI of the PFA (Polarimetry Focusing Array) instrument and co-I of the WFM (Wide Field Monitor) instrument.
- ASI is the lead funding agency in Europe.
- The Italian technology of large-area Silicon Drift Detectors is the enabling technology for both the LAD and the WFM.
- The Italian technology of Gas Pixel Detector is the enabling technology of the PFA (Polarimetry Focusing Array) instrument.

Soft Response

Large area

Polarization

Monitoring

Payload	Parameter	Specification
SFA	Energy range	0.5-10 keV
	Effective area	>7000 cm^2 @1 keV, >5000 cm^2 @6 keV
	Energy resolution	<180 eV FWHM @6 keV
	FoV/HPSD	12 arcmin / 1 arcmin
	Focal plane detector	Pixelated SDD (19 pixels)
LAD	Energy range	2-30 keV (extended: 30-80 keV for out-FoV)
	Effective area	34000 cm^2
	Energy resolution	<240 eV FWHM @6 keV
	FoV	1° (FWHM)
	Detector	Large area SDD (640 units, 40 Modules)
PFA	Energy range	2-10 keV
	Effective area	>900 cm^2 @2 keV (including QE)
	Energy resolution	1.2 keV FWHM @6 keV
	FoV/HPD	12 arcmin / 20 arcsec
	Focal plane detector	GPD (4 units)
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

Spectroscopy Focusing Array (Spectroscopy)

Large-Area Detector (collimated) (Timing)

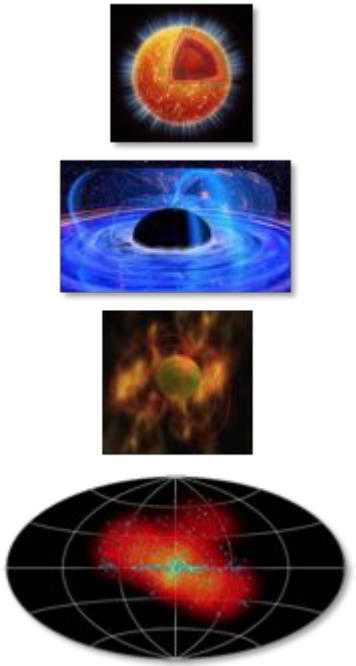
Polarimetry Focusing Array (Polarimetry)

Wide-Field Monitor (Transient Monitoring)

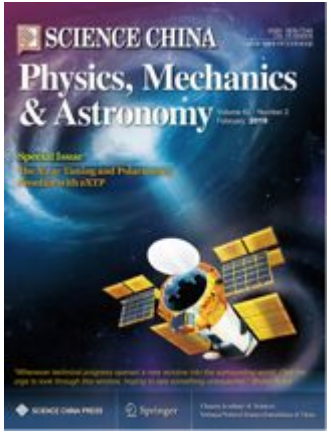
eXTP Science Drivers

Study of matter under extreme conditions of gravity, density and magnetism.
Simultaneous, high-throughput spectral, timing and polarimetry observations.

- Constrain the Equation of state of the supra-nuclear density matter in the interior of neutron stars.
- Accretion physics in the strong-field regime of gravity and tests of General Relativity in neutron stars and black holes over the mass scale.
- Physics of light and matter in the presence of ultra-strong magnetic fields in magnetars and X-ray pulsars.
- Multi-purpose observatory and wide-field monitoring for transients (and e.m. counterparts of GWs). Rapid follow-up.



eXTP Science Themes



Dense Matter: which is the state of matter at supranuclear densities?

Strong Gravity: what are space-time properties under extreme gravity?

Strong magnetism: how does light behave with ultra-strong B fields?

Observatory Science: multimessenger astroparticle

SCIENCE CHINA
Physics, Mechanics & Astronomy
• Invited Review •
Special Issue: The X-ray Timing and Polarimetry Frontier with eXTP
February 2019 Vol. 62 No. 2: 029504
https://doi.org/10.1007/s11433-018-9297-0

Accretion in strong field gravity with eXTP

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Physics, Mechanics & Astronomy
• Invited Review •
cial Issue: The X-ray Timing and Polarimetry Frontier with eXTP
February 2019 Vol. 62 No. 2: 029506
https://doi.org/10.1007/s11433-017-9186-1

Observatory science with eXTP

Jean J. M. in 't Zand[1*], Enrico Bozzo[2], JinLu Qu[3], Xiang-Dong Li[4], Lorenzo Amati[5], Yang Chen[4], Immacolata Donnarumma[6,7], Victor Doroshenko[8], Stephen A. Drake[9], Margarita Hernanz[10], Peter A. Jenke[11], Thomas J. Maccarone[12], Simin Mahmoodifar[9], Domitilla de Martino[13], Alessandra De Rosa[7], Elena M. Rossi[14], Antonia Rowlinson[15,16], Gloria Sala[17], Giulia Stratta[18], homas M. Tauris[19], Joern Wilms[20], XueFeng Wu[21], Ping Zhou[15,4], Iván Agudo[22], Diego Altamirano[23], lean-Luc Atteia[24], Nils A. Andersson[25], M. Cristina Baglio[26], David R. Ballantyne[27], Altan Baykal[28], ud Behar[29], Tomaso Belloni[30], Sudip Bhattacharyya[31], Stefano Bianchi[32], Anna Bilous[33], Pere Blay[33], João Braga[34], Søren Brandt[35], Edward F. Brown[36], Niccolò Bucciantini[37], Luciano Burderi[38], dward M. Cackett[39], Riccardo Campana[5], Sergio Campana[30], Piergiorgio Casella[40], Yuri Cavecchi[41,25], Frank Chambers[15], Liang Chen[42], Yu-Peng Chen[3], Jérôme Chenevez[15], Maria Chernyakova[43], ChiChuan Jin[44], Riccardo Ciolfi[45,46], Elisa Costantini[1,15], Andrew Cumming[47], Antonino D'Aì[48], Zi-Gao Dai[4], Filippo D'Ammando[49], Massimiliano De Pasquale[50], Nathalie Degenaar[15], Melania Del Santo[68], Valerio D'Elia[40], Tiziana Di Salvo[51], Gerry Doyle[52], Maurizio Falanga[53], XiLong Fan[54,55], Robert D. Ferdman[56], Marco Feroci[7], Federico Fraschetti[57], Duncan K. Galloway[58], ngelo F. Gambino[51], Poshak Gandhi[59], MingYu Ge[3], Bruce Gendre[60], Ramandeep Gill[61], Diego Götz[62], Christian Gouiffès[62], Paola Grandi[5], Jonathan Granot[63], Manuel Güdel[63], Alexander Heger[58,64,121], Craig O. Heinke[65], Jeroen Homan[66,1], Rosario Iaria[51], Kazushi Iwasawa[67], Luca Izzo[68], Long Ji[4], Peter G. Jonker[1,69], Jordi José[17], Jelle S. Kaastra[1], Emrah Kalemci[70], Oleg Kargaltsev[71], Nobuyuki Kawai[72], Laurens Keek[73], Stefanie Komossa[19], Ingo Kreykenbohm[20], Lucien Kuiper[1], Devaky Kunneriath[74], Gang Li[3], En-Wei Liang[75], Manuel Linares[17], Francesco Longo[76], angJun Lu[3], Alexander A. Lutovinov[77], Denys Malyshev[8], Julien Malzac[78], Antonios Manousakis[79],

SCIENCE CHINA
Physics, Mechanics & Astronomy
• Invited Review •
Special Issue: The X-ray Timing and Polarimetry Frontier with eXTP
February 2019 Vol. 62 No. 2: 029503
https://doi.org/10.1007/s11433-017-9188-4

Dense matter with eXTP

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SCIENCE CHINA
Physics, Mechanics & Astronomy
• Invited Review •
Special Issue: The X-ray Timing and Polarimetry Frontier with eXTP
February 2019 Vol. 62 No. 2: 029505
https://doi.org/10.1007/s11433-018-9234-3

Physics and astrophysics of strong magnetic field systems with eXTP

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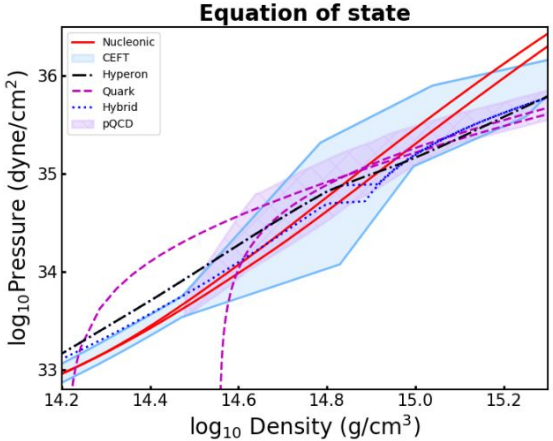
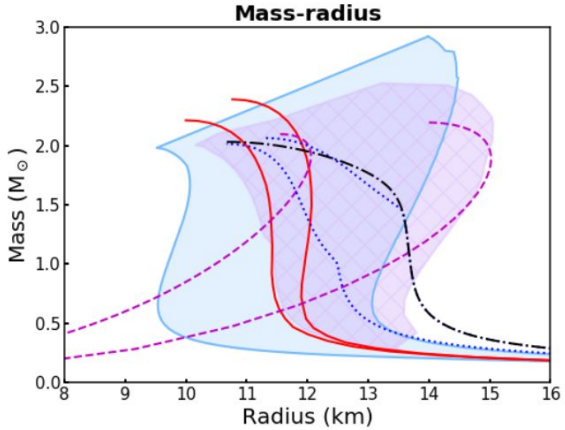
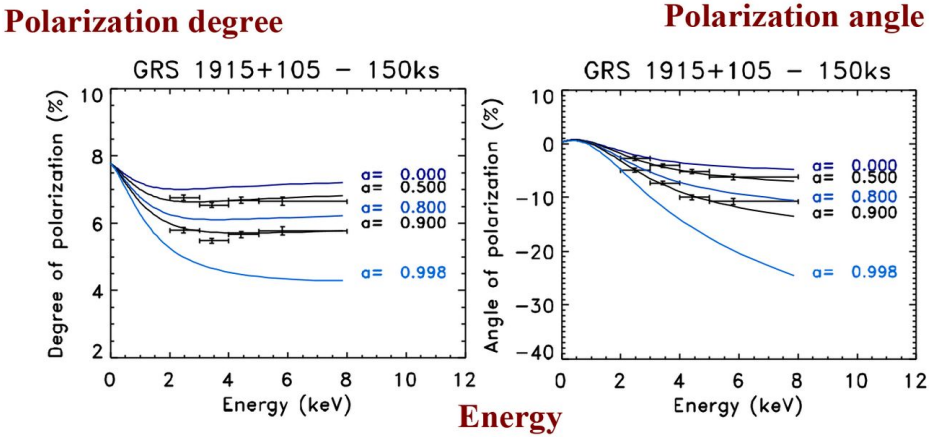
eXTP Science - Dense Matter

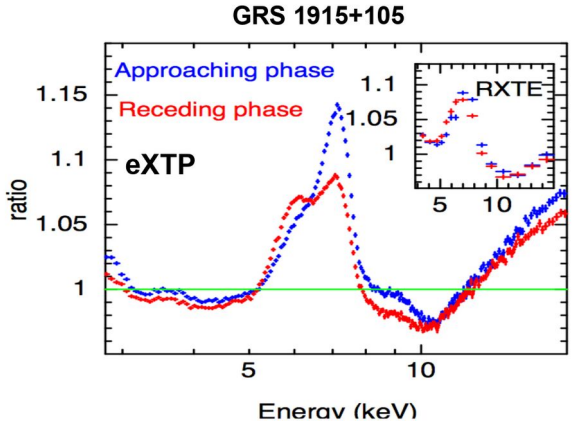




- Explore the QCD phase diagram (complementary to laboratory experiments)
- NS equation of state <-> mass-radius diagram (via the structure equations)
  - Different microphysics give different curves
- Current constraints: spectral modeling / pulsar timing in compact binaries
- eXTP will allow detailed pulse-profile modeling of accretion-powered pulsars
  - Information about M and R in the normalisation and harmonic content of the pulse profile
  - Polarization measurements allows to constraint the geometry of the source

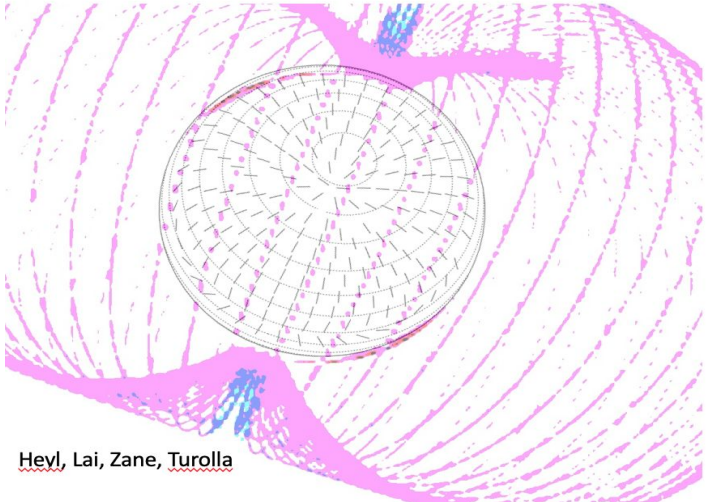
eXTP Science - Accretion in strong field gravity

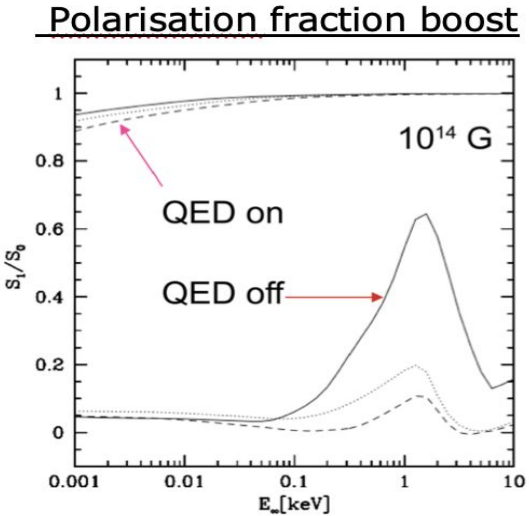




- Broad Fe lines
  - External illumination of the disk, broadened by a series of relativistic effects
- Quasi-Periodic Oscillations
  - Very strong probe of the relativistic dynamics in the inner part of the disk
- (And combination of the two)
  - Study of the Fe line shape as a function of the QPO phase
- Characteristic change with energy of the polarization angle/degree

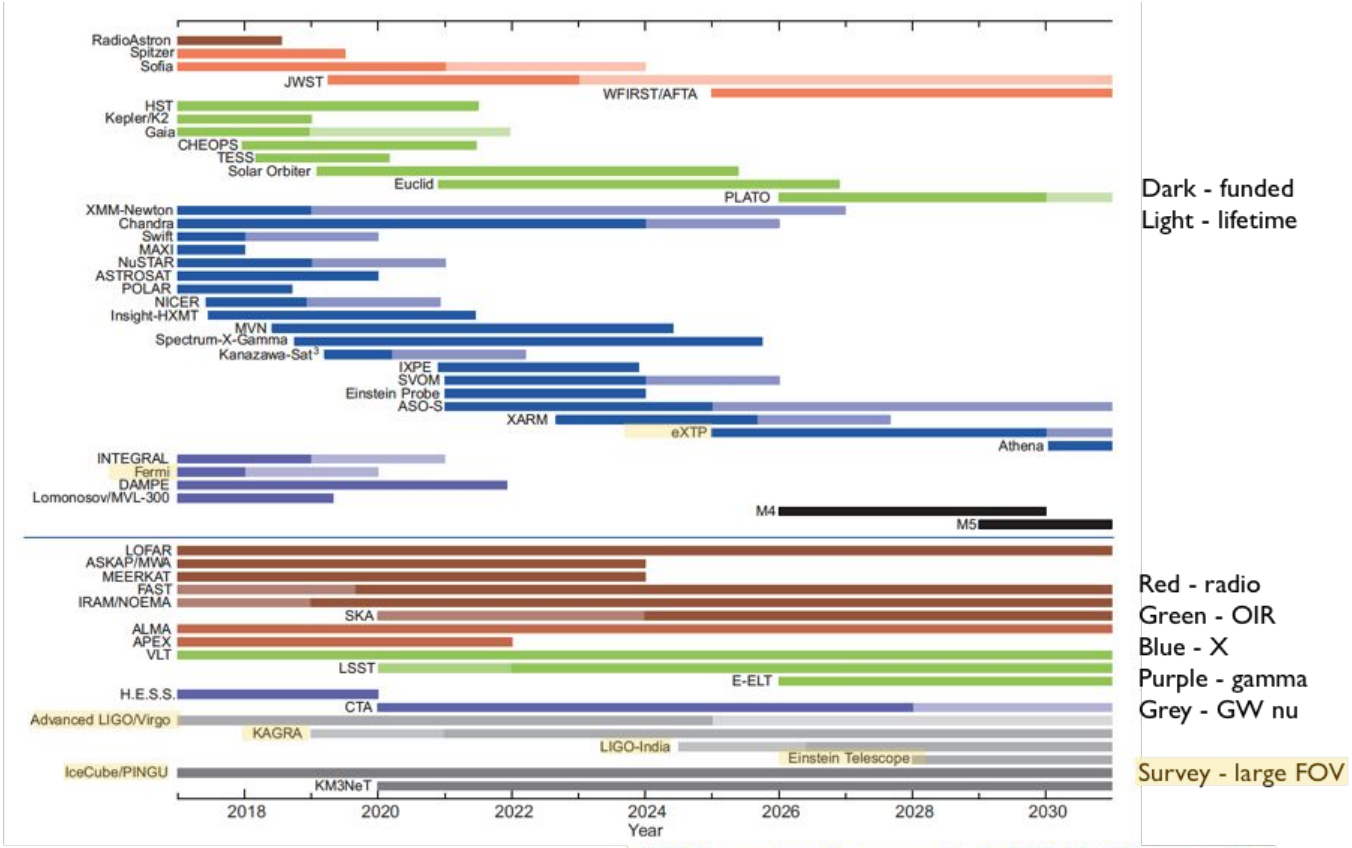
eXTP Science - Strong magnetism





- QED predicts vacuum birifringence in a high-enough magnetic field
  - O and X modes have different indices of refraction
- Magnetars provide an astrophysical environment in which this can be confirmed for the first time
  - Maximal polarization evolution in the NS magnetosphere
  - Comparatively small effects on the X-ray spectra

eXTP Science - Observatory Science



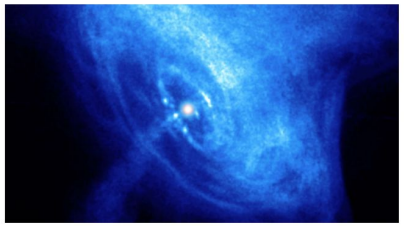
eXTP Observatory Science - doi 10.1007/s11433-017-9186-1

INFN Heritage for PFA

IXPE Flight Models delivered for integration on S/C and planned April 2021 launch

12 MAGGIO 2020

LA PULSAR DEL GRANCHIO AI RAGGI X: POLARLIGHT CONFERMA IL SUCCESSO DELLA TECNOLOGIA TUTTA ITALIANA



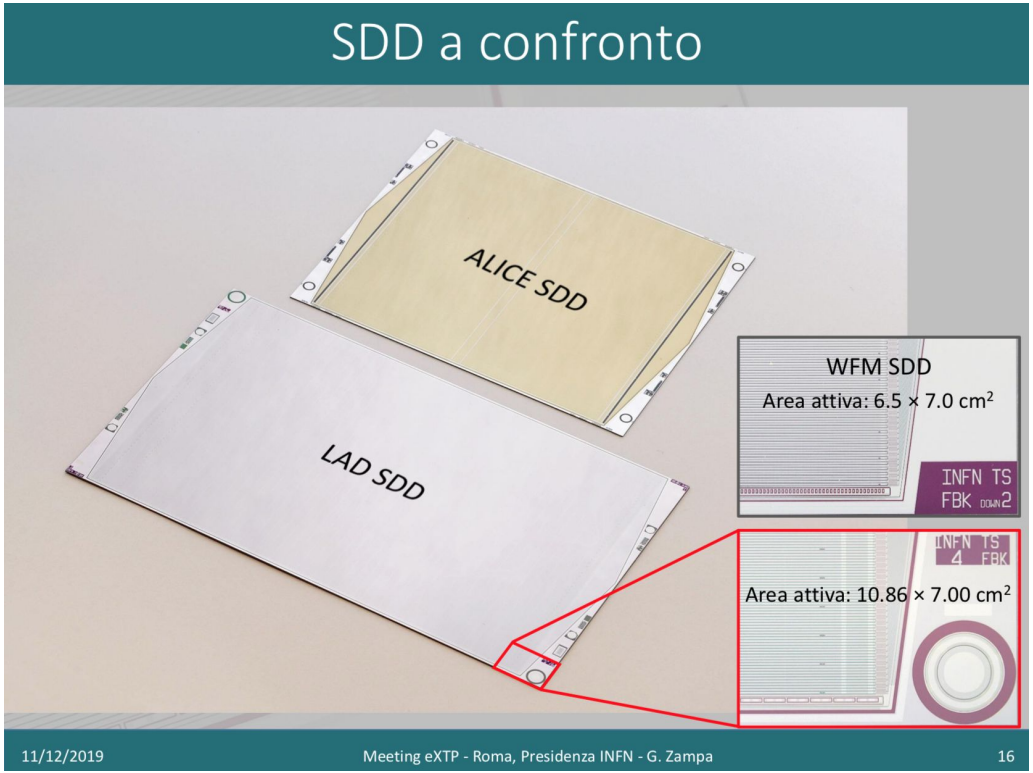
Prendi un nanosatellite, aggiungi dei rivelatori nei raggi X super efficienti di derivazione tecnologica italiana e lancialo in orbita per studiare la più celebre delle pulsar, quella del Granchio. Questa potrebbe essere, in estrema sintesi, la "ricetta" della missione spaziale cinese PolarLight, i cui primi risultati vengono pubblicati in un articolo sulla rivista Nature Astronomy. Il team di PolarLight, guidato da Hua Feng della Tsinghua University di Pechino e a cui partecipano ricercatori dell'Istituto Nazionale di Fisica Nucleare (INFN) e dell'Istituto Nazionale di Astrofisica (INAF), avrebbe registrato una diminuzione del grado di polarizzazione della radiazione emessa dalla pulsar Granchio, a cavallo di un 'glitch' osservato nel luglio del 2019. I 'glitch' sono delle rapide accelerazioni della rotazione della stella di neutroni dovute a un riassestamento repentino del suo nucleo. Questa variazione potrebbe essere legata a un riaggiustamento della magnetosfera della pulsar e alla conseguente variazione col tempo dell'angolo di polarizzazione della radiazione di alta energia emessa. Con questi suoi primi risultati, la missione PolarLight riapre la finestra della polarimetria nei raggi X, dopo 45 anni dal lancio del satellite statunitense OSO-8.

PolarLight measurement of Crab polarization
Nature Astronomy, 2020 may

https://home.infn.it/it/comunicazione/news/4020-la-pulsar-del-granchio-ai-raggi-x-polarlight-conferma-il-successo-della-tecnologia-tutta-italiana

Heritage for Silicon Drift Detector for LAD and WFM

- SDD production for ALICE
- Updates for large-area, low-power, space qualified devices for X-ray missions in space
- LOFT phase-A mission study for ESA

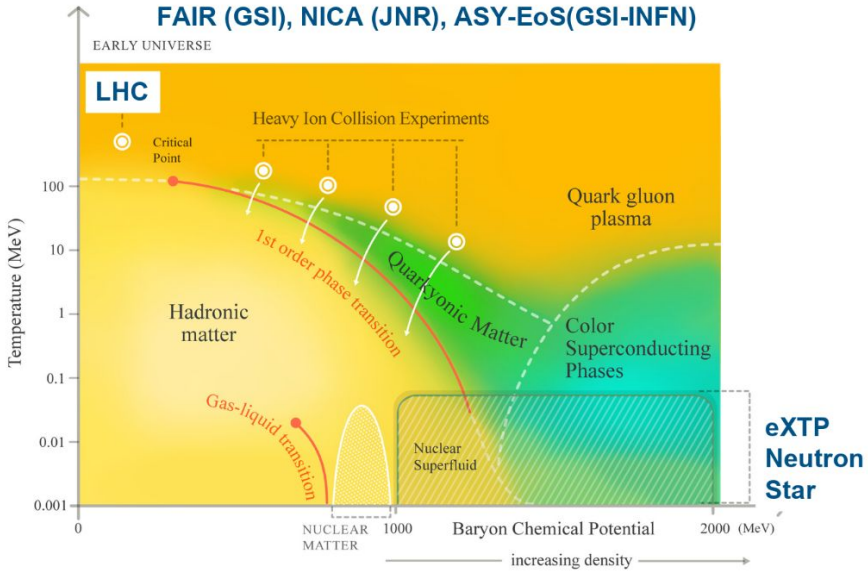


Conclusions

- eXTP will be next reference X-ray Observatory
  - Synergy of four instruments performing simultaneous observations
  - Open to the worldwide Scientific Community according to the International standards
- Two enabling technologies largely developed within INFN
  - Gas Pixels Detectors
  - Large-area Silicon-Drift Detectors
- Aligned with interests of nuclear theorists and MW/GW community
- New activity in CSN 2
  - Will include IXPE and eXTP
  - Two detector teams: GPD (Pisa, Torino) and SSD (Trieste, Trento, Perugia, Roma2)
  - Detailed proposal being prepared for July

Backup

eXTP Science - Dense Matter



Explore the phase diagram of QCD

- Complementary to laboratory experiments
- Low temperature, high density (10x the normal density in atomic nuclei)

eXTP - schema organizzativo gruppi INFN

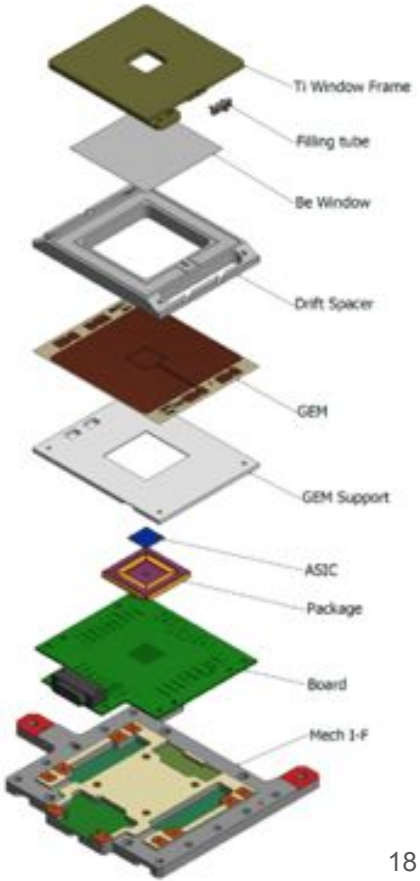
- Singola sigla IXPE + eXTP
  - Interessi scientifici comuni e intersezione di comunità esistenti
    - Detector teams: GPD + SDD
    - Astroparticle and multimessenger scientists
  - Proposal in preparazione per CNS2 in luglio
- Gruppi IXPE - almeno 12.5 FTE (9.5 @ Pisa, 3 @ Torino)
- Gruppi SDD - Trieste, Trento, Perugia, Roma2
- Gruppo teorico - in costruzione

eXTP/PFA - schema di finanziamento

- Simile a IXPE, grossomodo:
  - acquisti, personale TD, ~50% missioni a carico ASI
  - facilities, personale TI, metabolismo laboratori e ~50% missioni a carico INFN
- Accordi con ASI
  - ASI-INAF per eXTP (~25k per attivita' PFA nel 2020)
  - ASI-INFN per IXPE (~2M) - spese in linea con finalita' accordo esistente per migliorare performance GPD e sistematiche su modulazione spuria e secular pressure changes
  - ASI-INAF per ADAM (~200k) - spese in linea con design e produzione 3a generazione ASIC (10x faster)

INFN Heritage for PFA

1. Established GPD technology at INFN
    a. Proprietary design of enabling ASIC
    b. GPDs integration & qualification line available
        i. IXPE completed with delivery of 17 GPDs + 4 Flight telescopes
    c. Readout Electronics design & implementation capability
        i. w/ technology transfer for outsourcing production
2. Dedicated team with two X-ray polarimetry missions
    a. NASA/SMEX IXPE and PolarLight on chinese Cubesat Tonghuan-1



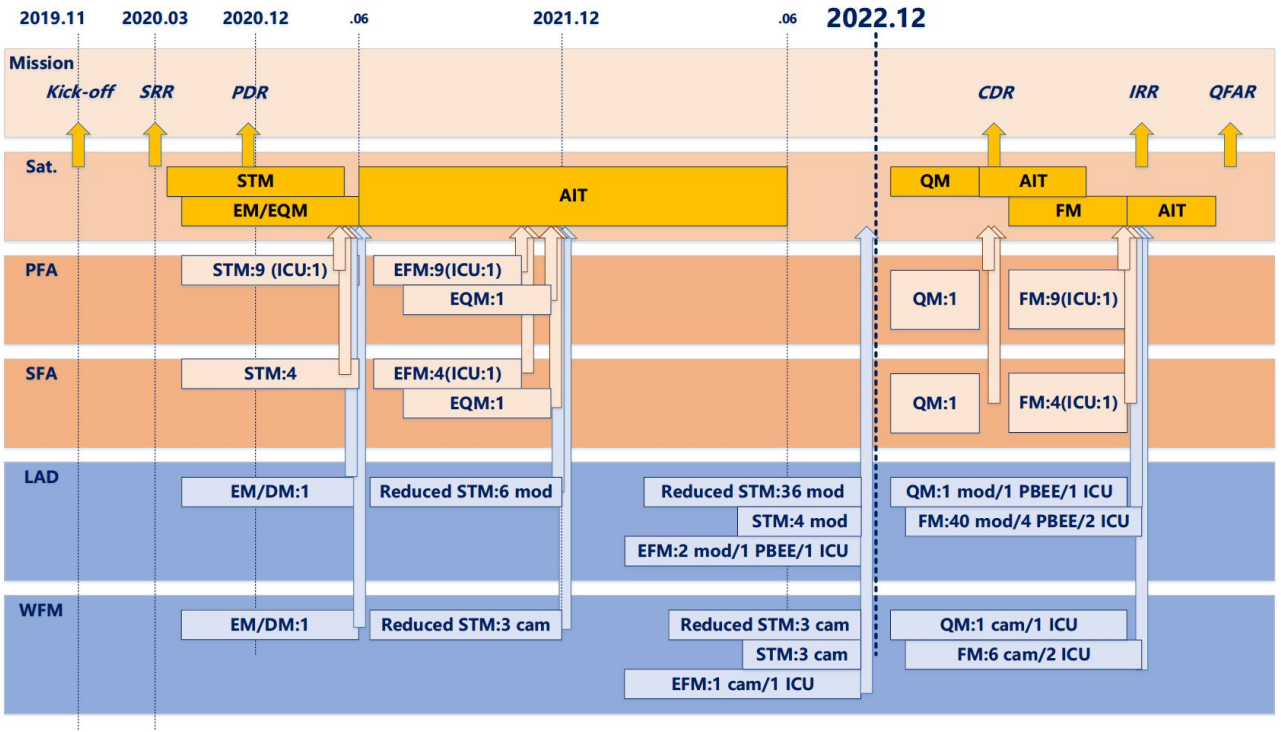
The eXTP International Consortium

PI Institute: IHEP

- CAS
- CNSA
- IHEP Beijing — Institute of High Energy Physics, Chinese Academy of Sciences
- Tsinghua University
- Tongji University
- CAST Beijing
- Microsat Shanghai

- Italy:
- Germany:
- France:
- Spain:
- Switzerland:
- Czech Republic:
- Poland:
- Denmark:
- The Netherlands:

Plan of eXTP


2019.11
2020.03
2020.12
.06
2021.12
.06
2022.12
Mission
Kick-off
SRR
PDR
CDR
IRR
QFAR
Sat.
STM
EM/EQM
AIT
QM
AIT
FM
AIT
PFA
STM:9 (ICU:1)
EFM:9(ICU:1)
EQM:1
QM:1
FM:9(ICU:1)
SFA
STM:4
EFM:4(ICU:1)
EQM:1
QM:1
FM:4(ICU:1)
LAD
EM/DM:1
Reduced STM:6 mod
Reduced STM:36 mod
STM:4 mod
EFM:2 mod/1 PBEE/1 ICU
QM:1 mod/1 PBEE/1 ICU
FM:40 mod/4 PBEE/2 ICU
WFM
EM/DM:1
Reduced STM:3 cam
Reduced STM:3 cam
STM:3 cam
EFM:1 cam/1 ICU
QM:1 cam/1 ICU
FM:6 cam/2 ICU

Schedule of PFA

- Phase B (24 months): Jan 2019 – Dec 2020 (funded by CAS)
  - DM/EM development
  - 2020.03 SRR
  - 2020.01 ASIC for DM/EM
  - 2020.06 GPD for DM/EM
  - 2020.07 DM/EM for PFA
  - 2020.11 PDR
- Phase C1 (24 months): Jan 2021 – Dec 2022 (funded by CAS)
  - 2020.07 ASIC for EFM (new version?)
  - 2021.03 GPD for EFM
  - 2021.06 EFM for PFA
  - 2020.10 ASIC for EQM
  - 2021.06 GPD for EQM
  - 2021.12 EQM for PFA
  - 2021.12 Instrument (SFA & PFA) STM & EFM delivery
  - 2022.09 AIT of system STM and AVM
  - 2022.12 KDP for further support
- Phase C2 (21 months): Jan 2023 – Sep 2024
  - QM development and verification
  - 2023.06 CDR
- Phase D (30 months): Oct 2024 – Mar 2027
  - FM delivery, S/C AIT
- Phase E1: Launch (6 months): Apr – Sep 2027
- Phase E2/3 (60 + 60 months): Oct 2027 – Dec 2037

We have completed the SRR and are in the process of EM design.

Collaboration on PFA - Partners and Contributions

Partners

- The Institute of High Energy Physics, Chinese Academy of Sciences (CAS/IHEP)
- Istituto Nazionale di Fisica Nucleare (INFN) - PI, TO
- Tsinghua University

IHEP Contributions

- lead the PFA instrument development and scientific studies.
- PFA mirror assembly developments
- develop the PFA focal plane camera with the GPD module
- conduct PFA instrument assembly integration test (AIT) and calibration

Collaboration on PFA - Contributions

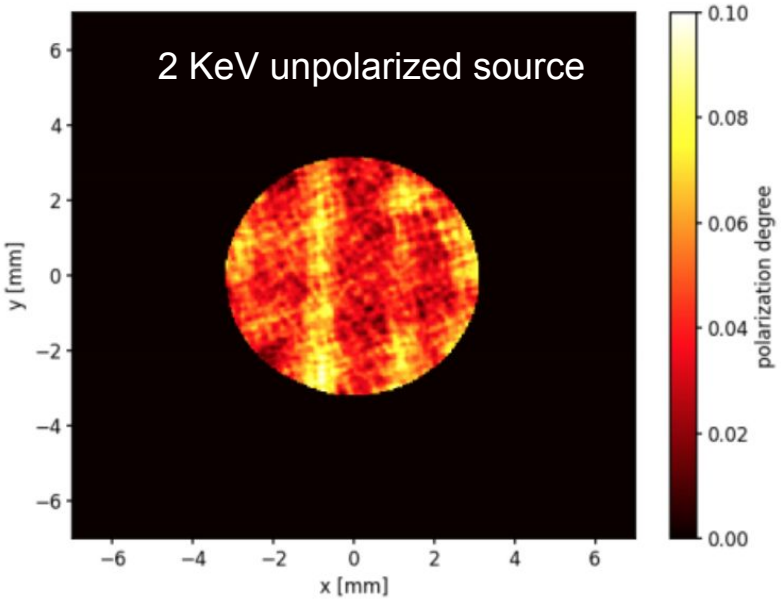
INFN contribution

- develop the new ASIC
- Develop, qualify and define new-design GPD (jointly with China)
- Support to Back End Electronics (BEE)
- Participation in calibrations
- Simulation and analysis packages
- Expertise

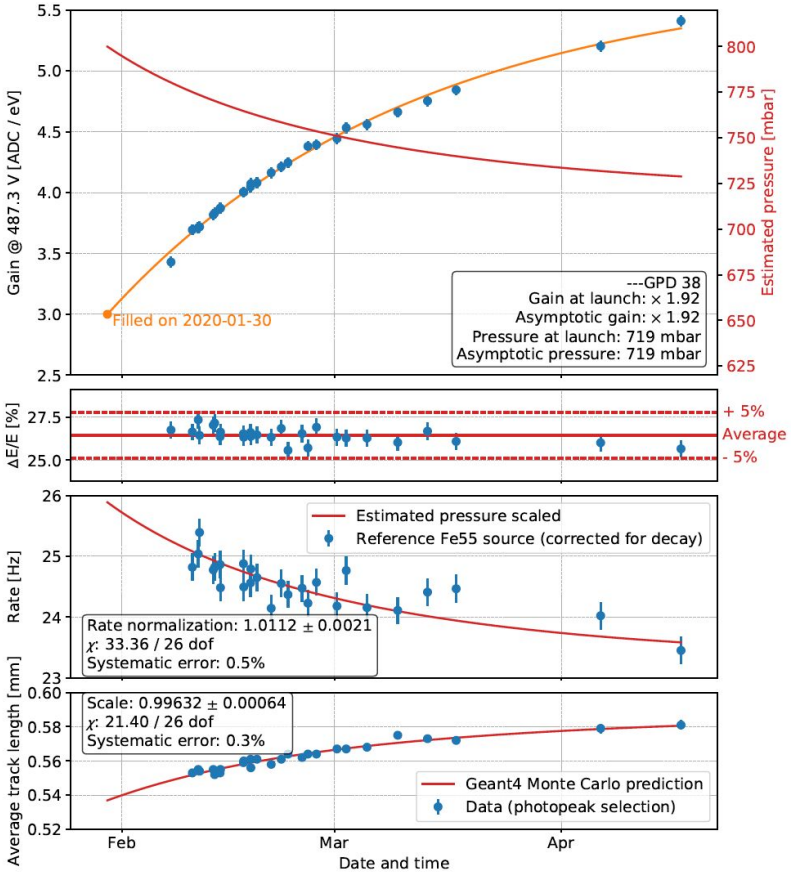
Challenges

1. eXTP science drivers and telescope design require 10x faster new ASIC
2. Minimize known systematics of IXPE GPDs
    a. spurious modulation
    b. performance evolution with pressure (gain and efficiency)
3. Program development
    a. Export control on exchanges with China
    b. eXTP tight schedule

Challenges - systematics



Residual modulation with GEM-related pattern



GPD performance evolution

Mission profile

Parameter	Value
Orbit	550 km, <2.5° inclination
Launcher	Long-March CZ-7 + upper stage, from Wenchang
Mass	4500 kg
Power	3.6 kW
Telemetry	3.2 Tb/day (X-band)
Ground Stations	Sanya, Malindi
Pointing	3-axis stabilized, < 0.01° (3-sigma)
Sky visibility	50% (goal 75%)
Mission Duration	5 years (goal 8 years)
Launch date	2027

eXTP Science - Observatory Science

Terrestrial Gamma-ray Flashes
Stellar flares
Cataclysmic variables
LMXBs
HMXBs
Accretion and ejection
Thermonuclear flashes on neutron stars
Pulsars
Tidal disruption events
Flares on AGN and Blazars
Gamma-ray bursts Supernova remnants
Galactic Center

eXTP synergy with other messengers:
Gravitational Waves, TeV, neutrinos